Countering WMD
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STURGIS LAST VOYAGE

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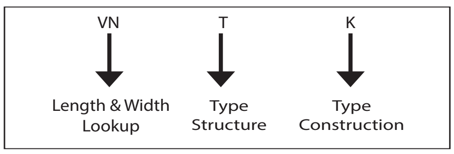

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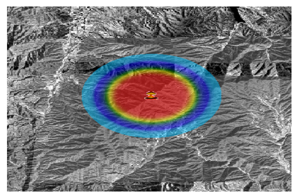

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DIRECTOR NOTES

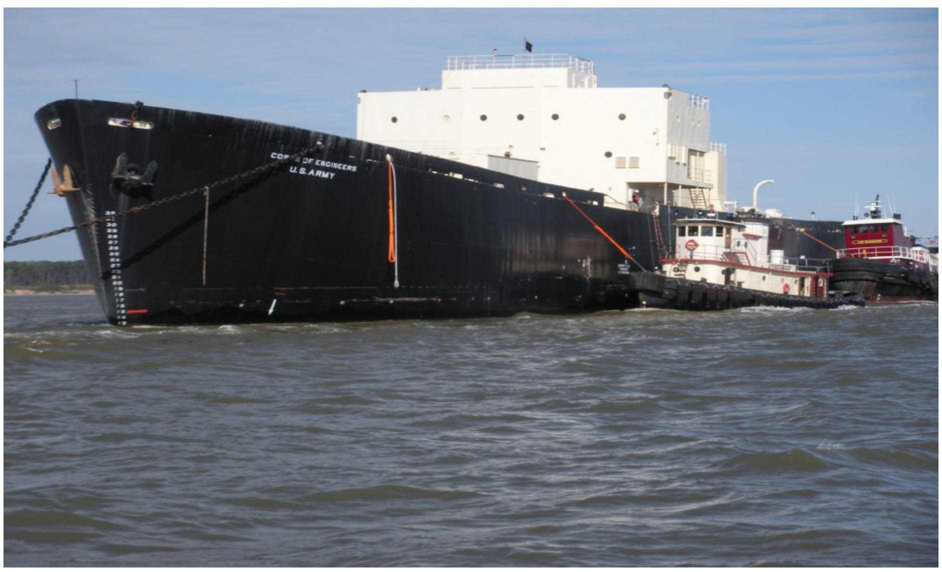
Mr. Daniel M. Klippstein
Director, USANCA
Deputy Director of Army Strategy, Plans and Policy Directorate, HQDA

As we closed out 2015 and now move into 2016, I want to share with you the significant progress USANCA and the Army, as well as the Department of Defense (DoD), have made in Countering WMD.

Let me start with the Joint Force. An important milestone was achieved with approval by the Joint Chiefs of Staff in October of the Joint Concept for Preventing the Use or Transfer of WMD. This paves the way for work to now begin on its companion document, the Joint Concept for CBRN Defense Operations. As the Joint Staff moves to develop the next Joint Concept, USANCA will take lead for HQDA to ensure all Army stakeholders participate in its development and Army equities are addressed to support development of CBRN capabilities to meet warfighting requirements. USANCA and HQDA's efforts will reflect our Army Operating Concept and will advocate for an integrated CBRNE approach as a necessary pre-condition for future operations in the development of any joint concept. We will also look to reinforce a CBRNE approach for any future environment in the drafting of the Army CWMD Strategy.

In September the Agency hosted and ran the U.S.-German Disablement Table Top Exercise (TTX), as part of HQDA's Staff Talks program with partner nations and allies. (NATO uses the term Disablement for what the U.S. calls Elimination). This first of its kind event at USANCA brought together CWMD and CBRN Defense leaders from the U.S. and Germany to gain an understanding of each Army's disablement capabilities, begin development of a joint TTP to improve interoperability, contribute to development of NATO'S WMD Disablement Concept, and explore areas of potential future collaboration regarding CBRN Disablement. The results of the TTX were briefed at the U.S.-German Armies Staff Talks in November, at which agreed-to-actions were approved that will continue the efforts began at USANCA with further bilateral events with the German Army in 2016 and 2017. USANCA is exploring the potential for expanding to events with other NATO partners as well.

Here at USANCA we celebrated the arrival of the Reactor Barge Sturgis into port at Galveston, TX in September for the final stages of its life as it undergoes decommissioning and dismantlement. The Sturgis is one of several Army nuclear reactors that are no longer operational, and are now being decommissioned. As we go to press with the CWMD Journal, activities to decommission and dismantle the Sturgis are approximately 25% complete, with the entire process scheduled to take two years. The Army Reactor Office (ARO) at USANCA will be monitoring the operations until the last of the hazardous material has been removed and the Sturgis is no longer to be permitted by the ARO. Decommissioning will involve proper disposal of the waste materials and disassembly of the reactor components in the barge. The Corps of Engineers is managing the execution of the disassembly and disposal of the barge. The project is expected to take about 2 years, at which time the barge will be removed from Army Reactor Program oversight. We've included an article in this edition on the history of the Sturgis and on the first shipment of radiological waste and material off the barge.



Reactor Barge Sturgis at Galveston, TX.

The Army's Biological Select Agents and Toxins (BSAT) Task Force continues its chartered work as a result of the inadvertent shipment of live anthrax spores from an Army laboratory. I had the opportunity of sitting on the executive steering committee for the task force. Additionally the Agency provideded subject matter experts who sat on various working and sub-working groups. The work of the task force resulted in the Secretary of the Army making decisions to consolidate leadership of two laboratories, and name the Office of the Surgeon General as the Army's responsible official for all DoD BSAT facilities. Work will continue in 2016 as several Army regulations will be updated to codify policy developed and approved during the work of the task force.

As part of the HQDA directed 25% reduction and simultaneous "delayering" effort, USANCA will be undergoing a reorganization in early 2016 to meet new structure and manning requirements. We were spared the deeper cuts that I anticipated, and were able to retain all of USANCA's civilian and military action officers, only taking cuts in the administrative areas of the Agency. By the next issue of the Journal I will be able to report that our reorganization will be complete as we move from a three division structure to five divisions. This reorganization will not impact our mission or functions of the Agency but will require some modifications in how we approach our tasks as we continue to adjust to an ever increasing complex world.

To close out my notes for this issue of the CWMD Journal I want to highlight a topic that is important to me as the proponent for FA52 Officers: The health of the FA52 career field and how do we increase the visibility and relevancy of FA52 Officers within our Army? This can be a difficult question to answer, given that more than 70% of our authorizations are in organizations outside the Army. We provide much needed expertise and manpower to important organizations such as the Defense Threat Reduction Agency, the National Nuclear Security Administration, the Combatant Commands, and Defense Intelligence Agency to name but a few. As our Army continues to undergo a drawdown of personnel, it is important to ensure Army leadership recognizes the importance that FA52 Officers have in meeting not just DoD's, but also the Army's missions. I will continue to look for opportunities to place FA52s into key positions – both in Joint/Interagency and Army organizations – to highlight the exceptional talent that exists in our career field.

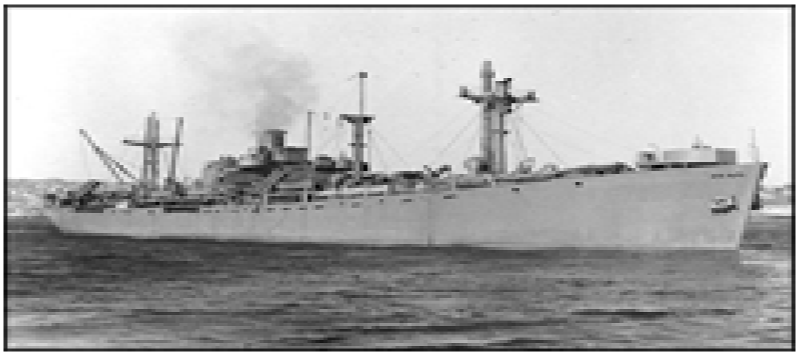
I look forward to us meeting this challenge in 2016.

Army's Historical Nuclear Power Barge, the STURGIS, takes its last Voyage

Mr. Phil Shubert
United States Army Nuclear and Countering WMD Agency

A Proud Heritage

The Army's only nuclear power barge began its service as the SS Charles H. Cugle in the Liberty Ship program. It was a Type Z-EC2-S-C5 Liberty ship and was built in Panama City, Florida. It was launched on 13 August 1945. Liberty ships were a class of cargo ships built in the United States during the World War II era. Noted for its simple, low-cost construction, they were mass produced on a scale without precedent. The ships were built in response to the loss of transport ships in the German U-boat campaign in World War II.



Entry into service as a Liberty Ship.

In 1961 a contract was awarded to the Martin-Marietta Corporation to convert the Liberty ship to the barge named STURGIS. The conversion involved removing the propulsion system and installing a pressurized water nuclear reactor, MH1-A. It was expected to be towed to a suitable mooring and set up to provide electrical power as needed. Its given name, STURGIS, was in honor of Lieutenant General Samuel D. Sturgis, Jr. and the engineer troops that built roads, airfields, ports, and bases from New Guinea to the Philippines during WW II. Later (1953) Lt. Gen Sturgis would become the Army Chief of Engineers.

STURGIS moored at Ft. Belvoir, VA.

Nuclear Power for the Panama Canal

In the late 1960s, power for the Panama Canal was a critical need. In a non-terrorist environment nuclear power made sense for deployment to remote areas. The ability to operate without a continuous supply chain of conventional fuels and huge savings of water compared to hydro generation were ideal attributes for the Panama Canal. The reactor supplied 10 MW (13,000 hp) electricity to the Panama Canal Zone from October 1968 to 1975. In 1968 the operation of the Panama Canal locks and the production of hydroelectric power for the Canal Zone were jeopardized by a Gatun Lake water shortage. Vast amounts of water were required to operate the locks and the water level on Gatun Lake fell drastically during the December-to-May dry season. The electrical power produced by the MH-1A plant aboard the Sturgis allowed it to replace the power from the Gatun Hydroelectric Station. This allowed the strained Gatun lake water be prioritized for navigation use in the canal. The Corps of Engineers estimated that more than one trillion gallons were freed up between October 1968 and October 1972 – enough to permit 15 additional ships to pass through the locks of the Canal each day.

STURGIS in the James River.

Retirement Years

It is important to note that the MH-1A reactor has no nuclear fuel or special nuclear material. The reactor was de-fueled, decontaminated for long-term storage, and sealed before being towed to the James River Reserve Fleet at Joint Base Langley Eustis, Virginia; where it was stored and maintained since 1978, except for times of periodic dry dock maintenance.[1]

Current Status in the port of Galveston

The following update from the Army Corps of Engineers.[2]

Since the STURGIS arrived in the Port of Galveston in April 2015, the team has kept very busy at the Malin International Shipyard. The locally hired project team has completed all required training and mobilization efforts, including establishment of site security, project site offices and fixtures for continued environmental monitoring of the air, water, sediment and external radiation exposure. Site utilities have been established to provide all needed power both dockside and onboard the barge, including lighting for general access. Due to the extreme heat conditions, the team also installed an air conditioning unit to provide climate control for the primary work area on the barge. This ventilation system includes HEPA filtration to ensure all radiological work areas are under negative pressure during decommissioning efforts. The team has also begun abatement activities (lead and asbestos) necessary to safely perform the decommissioning activities.

As an additional safety protocol to ensure our plans going forward are appropriate, in July 2015 we completed entry into the reactor containment area to get additional radiological dose readings on some of the larger components to be removed later in the decommissioning process. These additional readings confirmed prior data used in the planning efforts. Additionally, the team completed a laser scan of the area that was used to produce a visual computer model of the reactor containment area and its components. This model is being used to support decommissioning planning, maximize our efficiency, minimize exposure times to our employees, and increase safety for all aspects of the decommissioning.

Training with the local Galveston Emergency Response services, to include Galveston County Fire Department, Galveston County Ambulance Authority, Galveston Police Department, Galveston County Sheriff's Department, Port of Galveston Police Department, UTMB (need to spell out what UTMB is), and Customs and Border Protection, has been completed. We will continue to keep our lines of communication open with these critical partners as work progresses.

The next major construction activity on site will be cutting large access hatches in the vessel. These hatches will be used later this fall or winter to be able to remove larger pieces off of the barge. After the hatches have been cut,

STURGIS at Pier in Galveston, Texas.

MH1-A Control Panel.

MH1-A STURGIS refueling room and spent fuel storage tank, 14 September 2015, lower deck.

low level radiological waste will begin to be removed from the barge. It will be packaged in Department of Transportation compliant containers within the containment area of the barge, lifted out of the barge, and prepared for transportation to the selected disposal facility.

Environmental monitoring has continued since her arrival in Port, and no evidence of radioactive material or increased radiation exposure from the STURGIS has been documented outside of the reactor containment area.

References

1. http://www.nab.usace.army.mil/Missions/Environmental/Sturgis.aspx.

2. http://www.nab.usace.army.mil/Missions/Environmental/Sturgis.aspx.

Biography

Mr. Phil Shubert currently heads the Army Reactor Office. He is a Mechanical Engineering graduate from the University of Tennessee and served in the Navy as an A6-e Intruder Bombardier/Navigator with over 200 carrier landings on the USS Forrestal. He later served as a Senior Reactor Operator for the Tennessee Valley Authority (TVA), where he supervised the loading of the first fuel assembly at Watts Bar and was the Unit Operating Supervisor for the initial critical for Watts Bar in 1996. From1997-2007 he served with the Joint Warfare Analysis Center (JWAC), a joint command located at Dahlgren Naval Base. From 2007- 2011, he was a manager for Alstom Power Inc., which is a French multinational conglomerate supplying steam turbines to American power plants. Phil returned to U.S. government service in 2011 as the Army Reactor Program Manager under the U.S. Army Nuclear and Countering WMD Agency (USANCA).



The hatch cover was lifted and the items were removed from the upper refueling room floor. The spent fuel rod transfer cask and the spent control rod transfer cask were packaged in supersacks (white bags) and then loaded into intermodals for truck transportation to the disposal facility.


The reactor containment vessel dome has been removed from the vessel and is being prepared for transport. It will be surveyed and packaged before being lifted off the vessel.

First Radiological Waste Shipment from STURGIS

The VNTK System

Martin W. Moakler. Ed. D.
United States Army Nuclear and Countering WMD Agency

INTRODUCTION

As an Officer within the nuclear enterprise, you may be assigned in a position where you are required to understand how to determine nuclear damage effects against targets. There have been numerous modeling codes designed to assist a nuclear planner in performing this function, such as: Nuclear Weapons Effects Database System (NWEDS), Probability of Damage Calculator (PDCALC), and Integrated Weapons of Mass Destruction Toolset (IWMDT). When using modeling tools such as PDCALC, it is important to have a base knowledge of the Defense Intelligence Agency (DIA) physical vulnerability system for building susceptibility to blast damage. The DIA has the responsibility to classify the nuclear effects vulnerability of targets.

VNTK SYSTEM

The system used to determine nuclear effects vulnerability is the DIA's physical vulnerability system for nuclear weapons targeting commonly known as the VNTK System. The system is based on damage assessment surveys from Hiroshima and Nagasaki. Using this information, the US Air Force derived physical vulnerability scales for building damage due to a 20 kiloton weapon blast wave. Through the years, these physical vulnerability scales have been enhanced and improved, resulting in the current Defense Intelligence Agency (DIA) VNTK system. Information in this article is paraphrased from the "Physical Vulnerability Handbook for Nuclear Weapons," by the Defense Intelligence Agency dated January 1992 (OGA 2800-92).

The Physical Vulnerability System (VN System) was originally designed by DIA to represent a target's susceptibility to blast damage. Targets are categorized within the system so that the effects of weapon yield, height of burst, blast wave duration, and probability of damage may be quickly accounted for in nuclear targeting and weaponeering problems. The system is suitable for large-scale strategic planning, wargames, and the targeting of individual targets. The components of the blast wave are overpressure, reflected overpressure, and dynamic pressure.

Overpressure in the blast wave acts in all directions and can be thought of a rapid increase in the air pressure above the ambient atmospheric pressure. As the target is engulfed by the blast wave, overpressure acts to crush it. This crushing pressure has a duration that is dependent upon the weapon yield as well as the peak overpressure. This pulse duration increases with the weapon yield and increases as the peak pressure falls off with increasing distance from the detonation.

Dynamic overpressure results from the transient velocity and density of the air and dust particles in the blast wave. Due to the target itself, which impedes the flow of the blast wave, a displacement force develops when the blast wave encounters the target. This causes a differential pressure on the target; dynamic pressures results in a slapping or dragging force. This force has a duration dependent upon the weapon yield and peak pressure levels. The dynamic pressure duration increases as the yield of the weapon increases and the duration increases as the peak dynamic pressure decreases as the distance increases from the burst. Dynamic pressure produces a relatively long-duration net translational force whose magnitude is dependent upon the weapon yield and size and configuration of the target.

Although all three components of the blast wave may act on a target resulting in different durations, usually one component is dominant in causing damage to the target. The dominant pressure is the damage mechanism for the target being considered for VNTK classification. Although the VN system was originally designed to represent target susceptibility to damage by a nuclear blast, its flexibility allows it to be used for describing target response to other damage mechanisms, e.g. ground shock, cratering, fire, EMP, etc. This article will only describe the VNTK target assessment for individual targets (e.g. buildings), equivalent target area targets, craters, and personnel.

DEFINITIONS OF DAMAGE LEVELS

The VN system utilizes primarily two desired levels of damage against targets. Each of these damage levels required a new VNTK to be calculated. The VNTK by itself is meaningless without knowing the desired level of damage and a description of the damage criteria associated with that level. All damage criteria are derived from these general descriptions of a level of damage and are then translated into a specific damage definition that forms the foundation for the vulnerability analysis for the VNTK. The following are general definitions established for use in describing levels of damage to targets and target elements:

SEVERE DAMAGE

A damage level that requires essentially complete reconstruction of replacement of one of more critical major elements of the target, plus major reconstruction, repair, or replacement of associated structures or equipment before and function can be performed. Severe damage precludes the use of the target for any functional purpose.

MODERATE DAMAGE

A damage level that requires major repairs to one or more critical elements of the target, plus major reconstruction, repair, or replacement of associated structures or equipment before the designed functions can be performed. Moderate damage precludes effective use of the target for its intended functional purpose.

INDIVIDUAL TARGET VNTK (I.E. BUILDINGS). Depicted is a typical VNTK.

The VNTK (see Figure 1.) is a four-position alphanumeric expression that represents a target's susceptibility to damage by nuclear weapon effects. The first part is a two-digit number that depicts the relative hardness of the target to a 20-kt nuclear weapon for a specified damage level; this is the Vulnerability Number (VN). The second part is a single character called the T-factor, which indicates the type of damage mechanism. The T-factor is a target type indicator. For this article, the T-factor can be "P" (susceptible to overpressure damage), "Q" (susceptible to dynamic pressure damage), "Z" (contact burst damage or crater), or "I" (personnel vulnerability indicator). The T-factor not only indicated the primary damage mechanism for the target, but also defines the rate of reduction of the probability of damage as the range between the burst and the target increases. The value associated with this falloff is called the damage function. The damage sigma is the square root of the ratio of the variance of the lognormal density function and the second moment of the density function. The damage sigma is a measure of the rate of falloff of the distance damage function as seen in Figure 2.

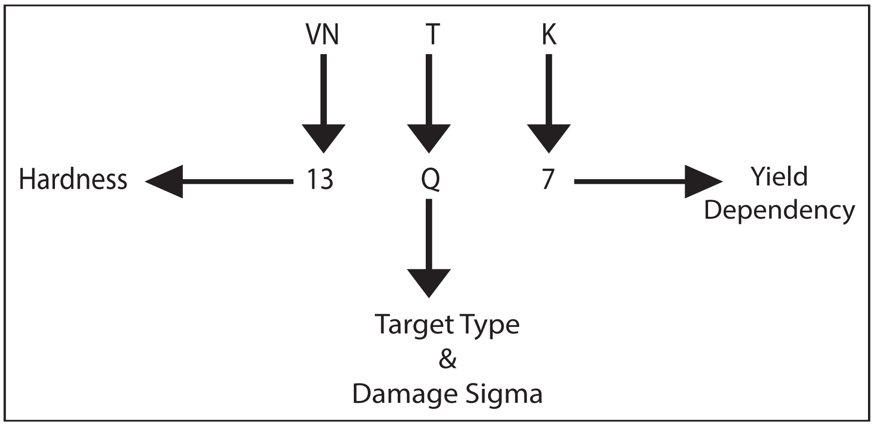


Figure 1. VNTK 13Q7.

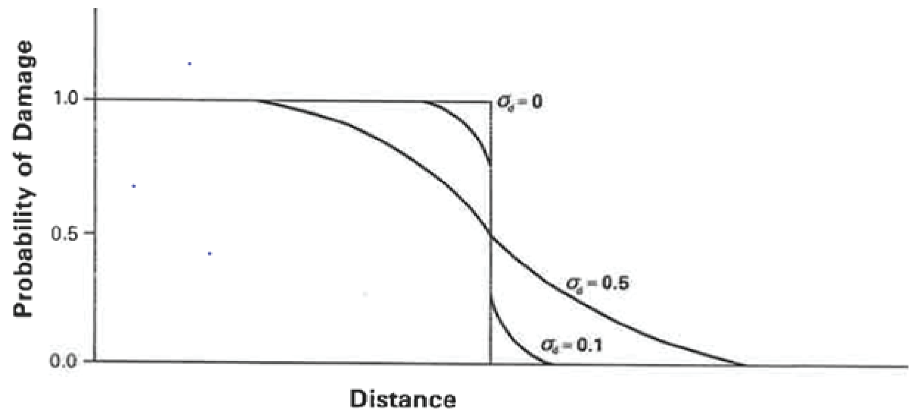


Figure 2. Distance Damage Sigmas.

For the VNTK T-factor, some typical damage sigmas are seen in Table 1. The third part of the VNTK is a single digit, the K-factor, which is a number used to account for the variability of the target response to different yields. Some targets may not be damaged at a given pressure produced by a 20-kt weapon, but may be susceptible to damaged dependent on the duration of the blast wave. The K-factor depicts the "ductility" of the target; most targets are sensitive to pulse duration of the blast wave. The K-factor has a value from 0 to 9, where lower K-factors are more brittle to a blast wave and higher K-factors are more ductile. The K-factor is used to obtain an adjusted VN (AVN) for any specific yield other that 20-kt yield. For yields less than 20-kt, adjustments are added to eh VN based on the K-factor, i.e. targets are harder at lower yields than 20-kt. For yields greater than 20-kt, adjustment is subtracted from the VN based on the K-factor, i.e. targets are softer at higher yields than 20-kt yield. No adjustment is needed if the yield is 20-kt or the target is assigned K = 0.

EQUIVALENT AREA TARGET VNTK

The VNTK system accommodates Equivalent Area Targets (ETA). ETAs are special targets that include bridges, dams, locks, and air-

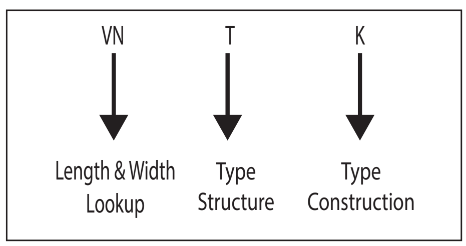


Figure 3. Equivalent Target Area VNTK.

T-Factor	Use	Damage Sigma Values
P	Overpressure	0.2
Q	Dynamic Pressure	0.3
Z	Contact Burst (Crater)	0.3

Table 1. Damage Sigma Values.

port runways. The general VNTK for an ETA is depicted in Figure 3. The ETA VN number (0-99) is keyed to target length and width dimensions. The T-factor depicts the type of structure the target. Indicators A, B, C are types of bridges, indicator D is a dam, indicator E is a lock, and indicator F is a runway. The K-factor (0-9) is keyed to specific type of target construction. Further expansion of the ETA VNTK is beyond the scope of this article.

CRATER VNTK

Contact vulnerability numbers (Z-VN) were developed to depict the vulnerability of structures to the cratering effects of nuclear weapons consistent with the vulnerability number (VN) system used for overpressure and dynamic pressure. The Z-VN can be used with the existing PDCALC software for predicting the probability of damage. This methodology compares the r_{50} for contact burst overpressure VN (P-VN) with the desired multiple of the apparent crater radius for the soil conditions of interest as a function of weapon yield. The assumed HOB for the contact burst is 0.5 meters and r_{50} is the range at which there is a 50 percent probability of damage. The methodology is not very easy and has been done by the Defense Threat Reduction Agency. Given a uniform distribution of like targets, the weapon radius (WR) is the radius of a circle centered at ground zero that contains as many targets undamaged inside as there are targets damaged outside. First, the WR for overpressure vulnerability numbers is computed using the method described in “Mathematical Background for the Physical Vulnerability System,” by the Defense Intelligence Agency dated July 1991 1992 (DDB-2800-91) (Unclassified) using a K-factor of zero. The range used by DIA is from 40P0 to 80P0. Next, convert these WR to r_{50} using the relationship

$$\mathbf{r_{50} - WR(1\text{-}\sigma_d^2)}$$

where σ_d^2 is the damage sigma normally assumed to be 0.3.

Next, you need to compute the apparent crater radius (CR_a) for the yields and soil conditions of interest using the methodology described in “Chapter 3 – Cratering, Ejecta, and Ground Shock (U)” DTRA EM-1, Defense Threat Reduction Agency for the range of yields from 20 to 2,000 kilotons and the five generic soil types discussed in Chapter 3, EM-1: dry soil, wet soil, dry weak rock, wet weak rock, and hard rock. These soil types are defined in Chapter 3, EM-1 and depend on total void fractions, the degree of water saturation in those voids, and strength of the material. Once you have the apparent crater radius, compute the appropriate multiple for CR_a equal to r_{50}. This will give you a multiplier for CR_a that equates to a 50 percent probability to attain the desired damage. After matching results with derived yield-pressure pairs to compute a P-VN that fits the data developed. After all of this was done, a look-up table was developed, now the Z-VN is reduced to the look up table shown in Table 2. For example, if you want a damage of 1.5 times the r_{50} apparent crater radius in wet soil, you would use the Z-VN value of 53Z0.

Multiple of Apparent Crater Radius	Dry Soil	Wet Soil	Dry Weak Rock	Wet Weak Rock	Hard Rock
0.5	*	71Z0	*	79Z0	*
1.0	74Z0	60Z0	72Z0	67Z0	75Z0
1.25	70Z0	56Z0	69Z0	64Z0	71Z0
1.5	67Z0	53Z0	66Z0	61Z0	68Z0
2.0	62Z0	48Z0	61Z0	56Z0	63Z0

Note: * - This multiple of apparent crater radius corresponds to an **r50** from a vulnerability number greater than 80Z0

Table 2. Z-VN for yields from 20 to 2,000 kilotons.

PERSONNEL VNTK

Personnel VNTKs are designed as lookup tables in PDCALC and prepared by USANCA using the legacy data contained in the Nuclear Weapons Effects Database System (NWEDS), which is the Army’s nuclear weapons effects computer model. Personnel VNTK have six levels of personnel damage/casualty depicted in Table 3.

PERSONNEL LEVELS OF DAMAGE	DAMAGE DEFINITIONS
Immediate Permanent Incapacitation (IPI)	Combat ineffective 3 minutes after exposure until death usually within 1 day
Immediate Transient Incapacitation (ITI)	Combat ineffective 3 minutes after exposure, brief recovery to performance degraded state, death within 6 days
Latent Ineffectiveness (LI)	Performance degraded state within 3 hours, death within 6 weeks
Fatality	Death of serious injury resulting in death within 30 days
Serious Injury	Serious injury that requires professional medical treatment and results in incapacitation for at least 60 days
Moderate Injury	Non-incapacitating injury that requires some kind of medical treatment (i.e., cuts, lacerations, minor burns, and mild radiation exposure).

Table 3. Personnel levels of damage definitions.

PERSONNEL SHELTERS	
Exposed to Thermal Radiation	Monumental Basement
Open (Thermally Protected)	Expedient Underground Shelters
Foxholes	Deliberate Underground Shelters
Wooden Frame Building	Underground Command Posts
Multistory Wall Bearing Building	Underground Civil Defense Shelters
Multistory Steel Frame Building	Tanks
Standard Basement	Armored Personnel Carriers

Table 4. Personnel Shelters.

POSTURE	IPI Tanks	ITI	LI	FATALITY	SERIOUS INJURY
Exposed to Thermal Radiation	30I1	30I2	30I3	30I4	30I5
Multistory Steel Frame Building	31I1	31I2	31I3	31I4	31I5
Multistory Wall Bearing Building	32I1	32I2	32I3	32I4	32I5
Standard Basement	33I1	33I2	33I3	33I4	33I5
Monumental Basement	34I1	34I2	34I3	34I4	34I5
Exposed to Thermal Radiation	35I1	35I2	35I3	35I4	35I5
Foxholes	36I1	36I2	36I3	36I4	36I5
Tanks	40I1	40I2	40I3	40I4	40I5
Armored Personnel Carriers	41I1	41I2	41I3	41I4	41I5
Deliberate Underground Shelters	42I1	42I2	42I3	42I4	42I5
Expedient Underground Shelters	43I1	43I2	43I3	43I4	43I5
Underground Command Posts	44I1	44I2	44I3	44I4	44I5
Underground Civil Defenses Shelters	45I1	45I2	45I3	45I4	45I5
In the Open, but Thermally Protected				50I4	50I5
Moderate Injury 51I0					

Table 5. Personnel VNTKs.

The Personnel VNTK depicts 14 different shelters (See Table 4). Like all the other VNTK numbers, the Personnel VNTK depicts a 50% probability that the desired casualty is attained. Personnel are vulnerable to airblast, initial nuclear radiation, and exposure to thermal radiation. These VNTK tables includes all three nuclear weapons effects. The casualty tables are built as a function of weapon yield and scaled Height of Burst. The T-factor for Personnel VNTK is usually "I" and entries into PDCALC follow this lookup table of Personnel VNTKs (See Table 5).

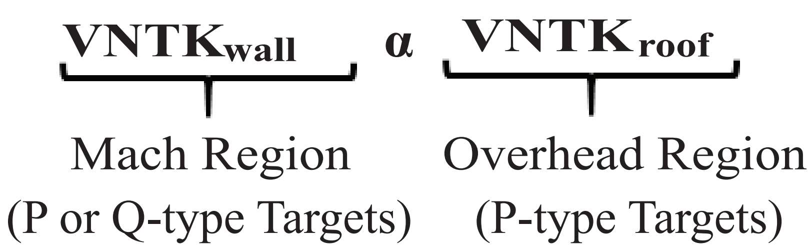


Figure 4. 2-VNTK Format.

2-VNTK

For urban and industrial targets, VNTKs have been expanded to 9 characters, known as the 2-VNTK. The 2-VNTK includes both a surface burst VNTK (wall vulnerability) and an overhead burst VNTK (roof vulnerability) (See Figure 4. for general format). The 2-VNTK includes a one character to encode time to maximum response (alpha character A-Z, see Table 6.). Figure 5. shows the regions for the 2-VNTK. The $VNTK_{roof}$ is for target top loading of the blast wave and can only be a P-type structure. $VNTK_{wall}$ is for the target side loading of the blast wave taking into account the reflection mach stem blast wave and can be a P-type or a Q-type structure.

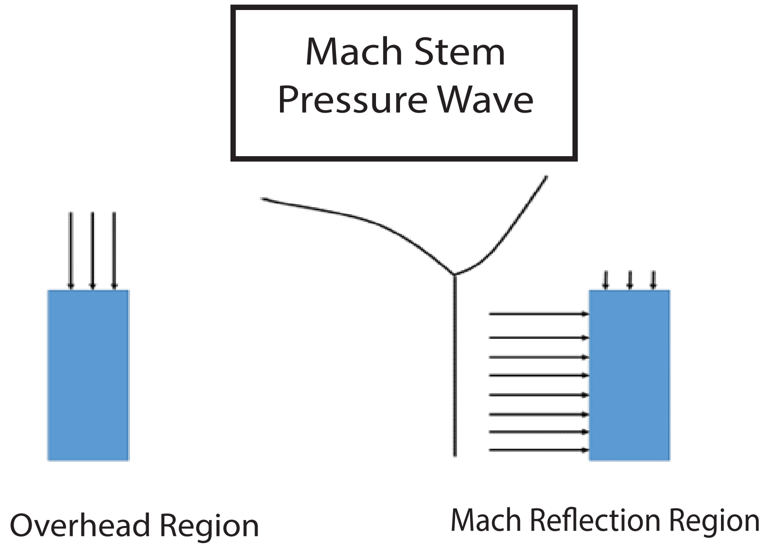


Figure 5. Blast Pressure Target Loading Mechanisms.

5th Character	α	5th Character	α	5th Character	α
A	*	J	0.6	S	1.05
B	0.2	K	0.65	T	1.1
C	0.25	L	0.7	U	1.15
D	0.3	M	0.75	V	1.2
E	0.35	N	0.8	W	1.25
F	0.4	O	0.85	X	1.35
G	0.45	P	0.9	Y	1.45
H	0.5	Q	0.95	Z	1.55
I	0.51	R	1.0		

Table 6. 2-VNTK: Time to Max Response.

The alpha character (α) in the 2-VNTK refers to a value used for Q-type structures to determine the time to maximum response, where Q_{dur} is the dynamic duration at the range associated with P50SB. The 2- VNTK uses Table 6. to determine the time to maximum response (tmax), where tmax = $Q_{dur}(\alpha/W^{0.25})$ where W is the weapon yield in kilotons. This article can only provide a basic level of understanding on how the VN system is used when conducting targeting with nuclear weapons. To utilize modeling software such as PDCALC the DIA VNTK system is needed to determine the probability of damage against a given target. For further information concerning the VNTK system, one should consult the "Physical Vulnerability Handbook for Nuclear Weapons," by the Defense Intelligence Agency dated January 1992 (OGA 2800-92), which is a classified document since the VNTK indicator is affixed to particular targets.

Biography

Dr. Moakler is the Chief, Analysis Division, U.S. Army Nuclear and Countering WMD Agency (USANCA) and a retired Army FA52 Colonel. His previous assignments include: Computer Systems Analyst, J5, NORAD; Associate Professor, Department of Physics, U. S. Military Academy; Commander 169th Engineer Battalion, Fort Leonard Wood, MO; Counterproliferation Branch Chief, J5 USFK, Korea; Chief, Nuclear Division, USANCA; Deputy Director, Technology Applications Directorate, Defense Threat Reduction Agency, Deputy Director, Weapons Effects Directorate, Defense Special Weapons Agency (DSWA); and Chief, Nuclear Division, USANCA. He is a graduate of the Army War College and the National Security Management Course. He earned an Education Doctorate from The George Washington University, M.S. in Nuclear Engineering and Computer Science from Rensselaer Polytechnic Institute; M.S. in Engineering Management from the University of Missouri-Rolla; and M.S. in Education from Old Dominion University.

White Sands Missile Range Directed Energy Systems Capabilities
Part I: Reltron System Facility

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INTRODUCTION

The mission area of the Survivability, Vulnerability, and Assessment Directorate (SVAD) located at White Sands Missile Range (WSMR), concerning high power electromagnetic (HPEM) environments and effects is derived from the three following DoD Instructions (DoDI):

1) DoDI 5000.02, Operation of a Defense Acquisition System, which requires developmental testing of Defense Acquisition Systems;

2) DoDI 3150.09, Chemical, Biological, Radiological and Nuclear (CBRN) Survivability Policy, to insure the survivability of mission critical systems in a CBRN environment. Here nuclear includes high altitude electromagnetic pulse (HEMP), which is generated by a nuclear weapon detonation;

3) DoDI 3222.3, DoD Electromagnetic Environmental Effects (E3) Program, that implements a DoD E3 program to ensure mutual electromagnetic compatibility (EMC) and E3 control among all ground, sea, air, and space-based electronic and electrical systems. E3 includes high power microwave (HPM) and HEMP.[1]

These instructions define the primary electromagnetic (EM) test and evaluation areas of the SVAD, which includes directed energy weapons (DEWs), E3, and electromagnetic pulse (EMP) as previously mentioned. As the Army becomes more dependent on electronic systems on the battlefield the potential threat of electromagnetic disruption, upset, and damage caused by HPEM sources, both red and blue, becomes more important along with a higher risk of mission failure.

This article will mainly focus on the directed energy sources available at WSMR for EM testing and subsequently the evaluation of electronic systems in a HEMP environment. Readers interested in a short introduction to HEMP test simulators or environments should review the EMP article in issue 11 of the CWMD Journal.[2] For completeness from a nuclear weapons effects perspective, in addition to EM testing, WSMR has ionizing radiation test facilities that can simulate the radiation effects from a nuclear detonation.[3]

High Power Electromagnetic (HPEM) Environments and Threats

The HPEM environment is illustrated in Figure 1. This figure denotes the relative spectrum strength as a function of frequency in Hertz (Hz), or cycles per second. Shown is the natural phenomena of lightning, which rolls off as the inverse and inverse squared of the frequency, the wide band nature of HEMP, the wide band source spectrum, such as ultra-wide band (UWB) and short pulse (SP), as well as narrow band sources, such as HPM and High Intensity Radiated Fields (HIRF). These narrow band sources are denoted by discrete frequencies with upward pointing arrows in the figure.

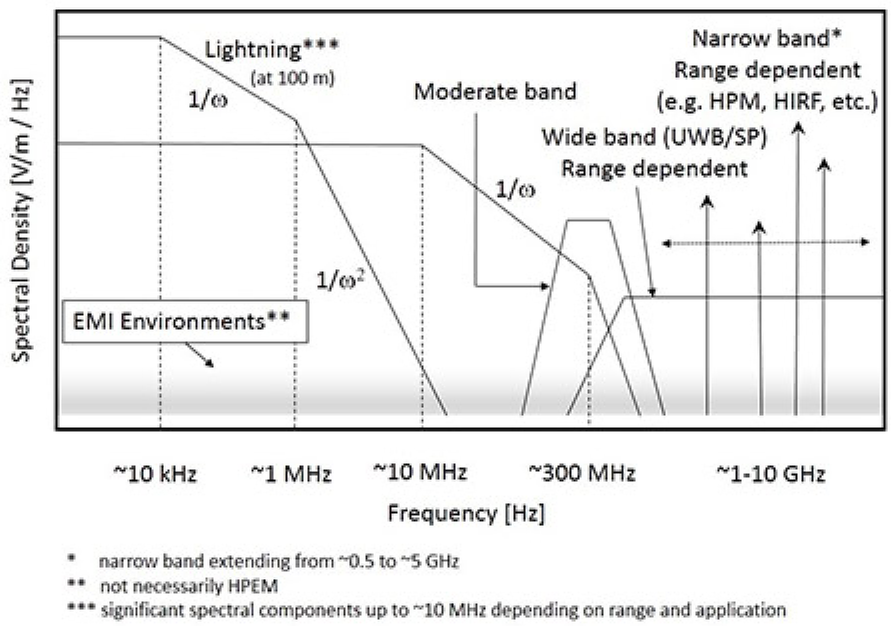

Figure 1. Illustration of the HPEM Environment. This picture denotes sources and potential threats of EM radiation, both manmade and natural. 1 MHz = 1 Mega Hertz = 1 million Hertz.

Also denoted in the figure is the electromagnetic interference (EMI) environment (background EM noise pollution). When interference is done on purpose, this usually denoted as intentional EMI, or IEMI for short. Note that even though HEMP can span a wide frequency range, wide band environments usually refer to high frequency sources (> 50 MHz) as depicted in Figure 1.

Lightning strikes and nearby strikes are a concern as an Army system may be subjected to large conducted or induced currents respectively, disrupting or damaging electronics. For HEMP the threat is from induced currents due to illumination by the EMP, which is analogous to that of a near lightning strike, where the radiated EM energy from the strike is conducted into the system. Narrow band sources pose a threat as the repetition and center frequency of the pulses can affect the operation of an electrical system, while for UWB, a broad range of frequencies illuminate a system, exposing possible frequency dependent vulnerabilities, and thereby enhancing the probability of a system kill, disruption, damage, or temporary malfunction.

High Power Microwave (HPM) Complex

As briefly described in the introduction the Survivability, Vulnerability and Assessment Directorate (SVAD) at White Sands Missile Range (WSMR), New Mexico, has a directed energy (DE) and E3 test capability. The E3 site is called the Joint Directed Energy Test Site, which tests blue related threats, such as electromagnetic interference (EMI) caused by friendly systems. The site also does radio frequency (RF) characterization. Discussion of this site will be a topic for a future article.

The main focus of this article is on the High Power Microwave (HPM) Complex, which contains the majority of the DE HPM sources and instrumentation which can be used for system and subsystem testing. The complex is a dedicated open air HPM testing facility (25 acres) with a reinforced concrete pad (120 ft x 120 ft). The site contains the HPM building (55 ft x 100 ft) which houses a 10 ton crane, two shielded screen rooms and a portable clean room. AC power is available in 110, 208, and 480 volts. An aerial view of the complex is shown in Figure 2. The HPM building is the large structure on the extreme right.

Figure 2. The HPM Complex is the large cluster of buildings on the right.

The HPM facilities are located next to the advanced fast electromagnetic pulse (AFEMP) simulator, which is on the left in Figure 2. Further information on the AFEMP can be obtained in reference 2. A closer view of the open air HPM test area, closest to the reader on the right in Figure 2., is shown in Figure 3. Note suspension posts of the AFEMP in the background on the right. For completeness, we also show a close up view of the AFEMP simulator in Figure 4.

HPM Sources and Facilities

The HPM Complex consists of a large Reltron (relativistic electron tube) system that is housed in the HPM building described in the previous section. The Reltron system occupies approximately half of the HPM building. The complex also contains four narrow band sources, designated with the prefix, NBTS (Narrow Band Threat Simulator), housed in trailer like containers for environmental protection and ease of transportability, one ultra-wideband source, and two other wide band sources. In order to give due diligence to each of the HPM sources within the complex, as well as keeping this article to a reasonable size, we will discuss the fore mentioned NBTS and UWB sources in a separate accompanying article (Part II and III), and concentrate specifically on the Reltron system.

Reltron System Sources and Facility

The operation of a Reltron tube is beyond the scope of this article; however it suffices to say that a Reltron tube generates a pulsed HPM source by the bunching and acceleration of electrons to relativistic energies. A Reltron tube,

Figure 3. Close up view of the HPM complex's open air test area. The bigger building on the right is the HPM building.

Figure 4. Close up view of the AFEMP. The EMP pulser is suspended in midair between the two poles.

that generates high power microwaves in the frequency range of 800-960 MHz, is shown in Figure 5a. Radiated power density depends on the tube type and distance from the source. For the Reltron tube shown in the figure, the radiated power density is greater than 21 Mega Watts per square meter at 15 meters. A Marx generator provides the required pulsed power to operate the tube. See Figure 5b. The generator consists of a 28 stage capacitor bank which provides a total voltage output of 1.4 million volts. A typical Reltron tube requires an operating voltage of 1 million volts.

The output of the Reltron tube shown in Figure 5a. is shown in Figure 5c. From this figure the frequency spectrum shows noticeable peaks at approximately 900, 1800, and 2700 MHz. The last two peaks are the harmonics of the

Figure 5a. An example of a Reltron tube. This tube can generate a peak electric field of 90,000 V/m (Volts per meter) at 15 meters, with an exposure area of 12 square meters.

Figure 5b. The Marx generator named after its inventor Erwin Otto Marx is used to drive the required Reltron tube.

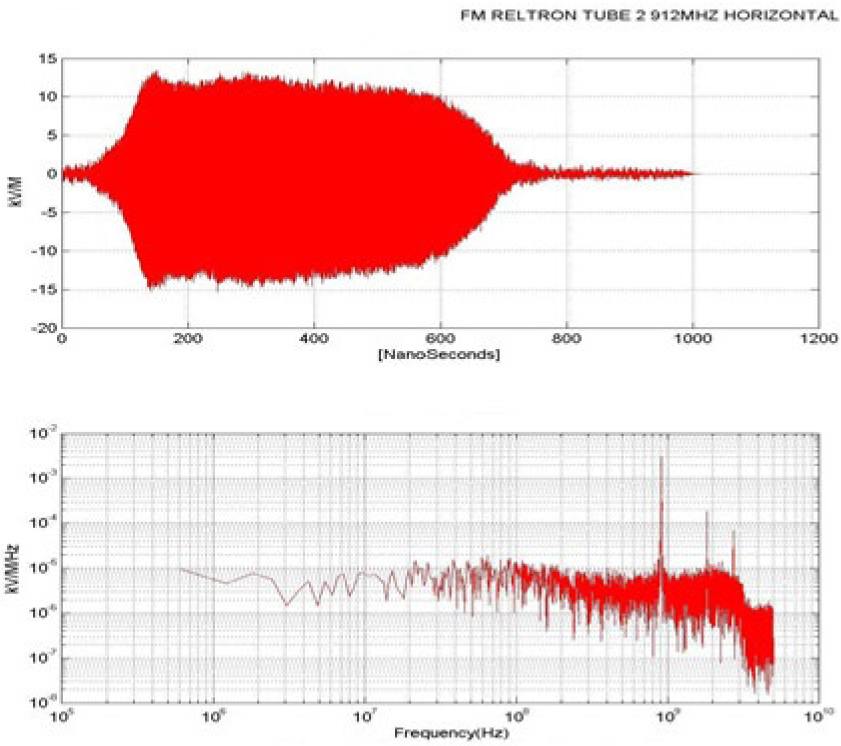

Figure 5c. The electrical field output of the tube shown in Figure 5a. in thousands of volts per meter (kV/m) and the frequency spectrum (kV per MHz) of the same tube.

Reltron Tube (No).	Center Freq (MHz)	Minimum Field Strength (kV/m) @15m	Illum Area (m²) @15m
0	600	50	12
1	750	50	12
2	880	50	12
3	1050	50	12
4	1300	50	12
5	1630	30	6.9
6	2000	30	6.9
7	2400	20	6.9
8	800	20	6.9

Each tube is frequency adjustable ~±10%

Operational   Delivered in FY 16   TBD

Table 1. WSMR DES Capabilities Part I Reltron System Facility.

tube's fundamental frequency output of 900 MHz. The narrowness of the fundamental peak indicates that the Reltron is a narrow band source device. From Figure 5c. one can also see that the maximum magnitude of the horizontal electric field obtained in this particular shot was approximately 15,000 volts per meter.

Figure 6a. WSMR DES Capabilities Part I Reltron System Facility.

Figure 7b. The interior of the Reltron control room with instrumentation.

Table 1. denotes currently available tubes that are operational. At the time of this article Tube 0 is also operational and Tube 5 is scheduled to arrive in January 2016. There is currently no plan for Tube 3 as other sources can meet current requirements. The Reltron system currently consists of 8 Reltron tubes, see Table 1., which collectively spans the frequency range of approximately 550 to 3000 MHz. Tube 2 in Table 1. is that shown in Figure 5a. Up to four Reltron tubes can be installed at a time and are housed in an oil insulated tank, see Figure 6a. foreground (lower right corner). The system's operational characteristics are: a repetition rate of 0-10 cycles per second (Hz), a 100 shot burst capability, a 500 nanosecond pulse width, and being 10% bandwidth tunable.

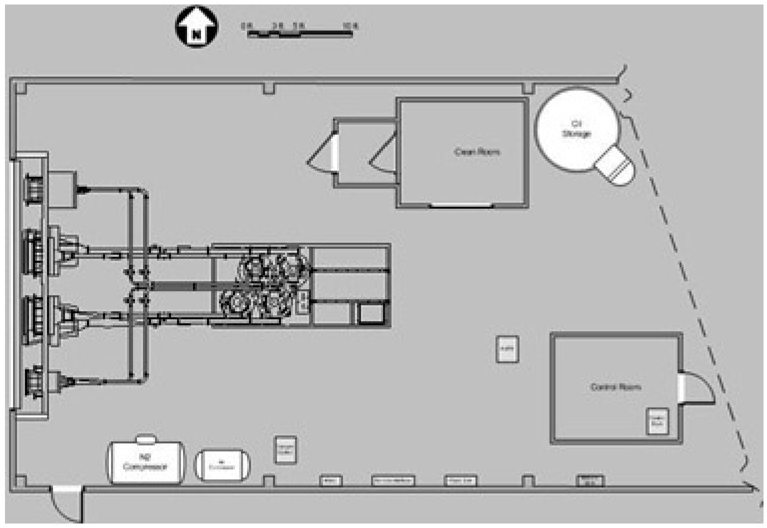

Figure 7a. WSMR DES Capabilities Part I Reltron System Facility.

Note that the antenna wall (silver colored) in Figure 6a., where the horn antennas are mounted, has eight different mounting locations. Figure 6b. shows the exterior view of the horn antennas shown in Figure 6a. with rexolite (a plastic) covers to maintain vacuum. The facility layout of the Reltron system and facility is given in Figure 7a. The Reltron facility is completely automated and is controlled from the shielded control room. See Figure 7a., lower right corner, and Figure 7b.

Figure 6b. WSMR DES Capabilities Part I Reltron System Facility.

For completeness we also present the available horn antenna systems that can be used in the Reltron system. The frequency response of each antenna is shown in Table 2. and Figure 8., which also shows the parts makeup of each antenna.

Frequency Range (MHz)	Input Waveguide	Length* (inches)	Output Aperture Width x Height[2] (inches)
700-960	WR1150	74.5	50.5 x 45.5
960-1450	WR770	55.5	41.7 x 36.5
1450-1800	WR510	74.3	34.0 x 22.5
1800-2200	WR510	55.9	26.0 x 17.5
2200-2600	WR340	51.7	22.0 x 15.0
2600-3000	WR340	43.5	18.0 x 12.0
*Includes 1/2 wavelength window at output aperture			

Table 2. Available horn antennas for use with the Reltron microwave source system.

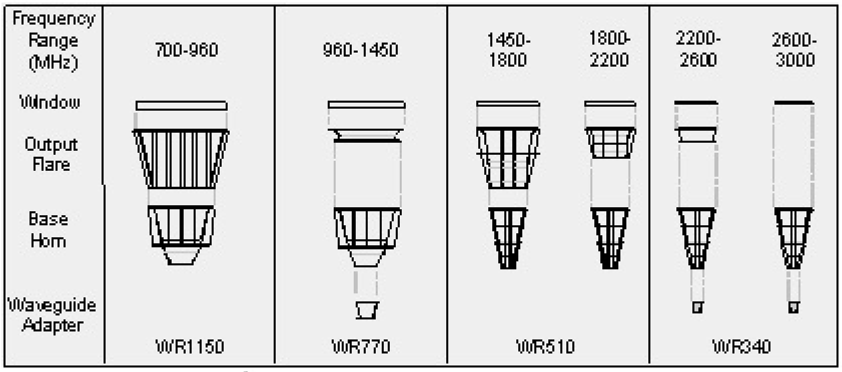

Figure 8. Pictorial representation of the horn antennas available at the Reltron System Facility.

Summary

In this article we described the Reltron system, its tube sources, and the facility in which the system is housed at the Survivability, Vulnerability and Assessment Directorate (SVAD) at White Sands Missile Range (WSMR). The Reltron system is a narrow band HPM system that spans the frequency range of approximately 550 to 3000 MHz, depending on the tube used. Such a system can be used to simulate a directed energy high power microwave weapon or other pulsed high power electromagnetic source. The descriptions of the facilities and hardware in this article are by no means complete. If the reader would like further information on the Reltron facility and/or its capabilities, one should contact the authors. Their contact information is provided at the end of this article.

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3. Brady, R., and Les, J., White Sands Missile Range Nuclear Weapon Effect Test and Evaluation Capabilities, Part II: Ionizing Radiation, Combating WMD Journal, Issue 11.

Biographies

Mr. Eric A. Berry is Electrical Engineer serving as the Director at the Survivability, Vulnerability and Assessment Directorate (SVAD) / White Sands Test Center (WSTC), in White Sands Missile Range, NM. He has a B.S. in Electrical Engineering from the University of Texas at El Paso and is currently pursuing a Ph.D. in Electrical Engineering from the University of Texas at El Paso. His technical expertise for over six years is in the field of high power microwave (HPM), near strike lightning (NSL), and high altitude electromagnetic pulse (HEMP) test and evaluation. His email address is eric.a.berry3.civ@mail.mil.

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Back Of The Envelope Answer On The Validity Of North Korea Underground Nuclear Detonations

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INTRODUCTION

Since 2005, North Korea announced that they set off three nuclear detonations underground and there is concern that they are getting ready to set up a fourth test. North Korea is a closed society with limited access to confirm that they actually set off nuclear weapons. There are three possibilities of what could cause a measurable disturbance, an earthquake, a large conventional explosion and a nuclear detonation. The purpose of this paper is to identify how to answer this specific question as a Nuclear Officer in the United States Army. I have seen various reports at different classifications, but I thought that there should be a simple "back of the envelope" way to determine whether there was a nuclear detonation. This article will cover the initial known data followed by an exploration of the methods to qualify and quantify a nuclear detonation. Finally, we will cover what the world put together for the comprehensive nuclear test ban.

Date	Magnitude	Location
09 Oct 2006 01:35:28 (UTC)	4.1	41.29°N 129.09°E
25 MAY 2009 00:54:43 (UTC)	4.5	41.306°N 129.029°E
25 MAY 2009 00:54:43 (UTC)	5.1	41.308°N 129.076°E

Table 1. USGS Seismic Data from North Korea events (USGS, 2006) (USGS, 2009) (USGS, 2013).[16,17,18]

Date	Yield Estimate	Location
09 Oct 2006	1000 t	Hwadae-ri, Korea
25 MAY 2009	2.5 kt	Hwadae-ri, Korea
25 MAY 2009	7 kt	Hwadae-ri, Korea

Table 2. CTBTO research results from North Korean Nuclear Tests.

Initially, we can look at seismic measurements from the United States Geological Survey (USGS). These three seismic events in Table 1. correspond with North Korean claims of nuclear detonations and the USGS lists these as underground nuclear tests. In addition, the Preparatory Commission for the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO), states that North Korea carried out the following tests listed in Table 2 (CTBTO-Nuclear Explosions, 2012).[6]Underground tests are nuclear explosions detonated under the surface of the earth. Underground nuclear tests emit negligible fallout compared to atmospheric testing. If an underground test vents to the surface it can produce radioactive debris. Seismic activity can relate to the yield of the nuclear device. The Comprehensive Nuclear-Test-Ban Treaty (CTBT) banned underground nuclear testing in 1996, but that has not stopped countries such as North Korea, India and Pakistan from carrying out underground tests (CTBTO-History, 2012).[4] In North Korea all three events are close to each otherf, located in the northeastern area of North Korea. On the overhead image on Figure 2., each one is color coded to correspond to Tables 1. and 2. On December 2nd, 2015, 38 North, a program of the US-Korea Institute at the Paul H. Nitze School of Advanced International Studies (SAIS) - Johns Hopkins University, published a new article. "New Nuclear Test Tunnel Under Construction at North Korea's Punggye-ri Nuclear Test Site" which displayed recent commercial satellite imagery in-

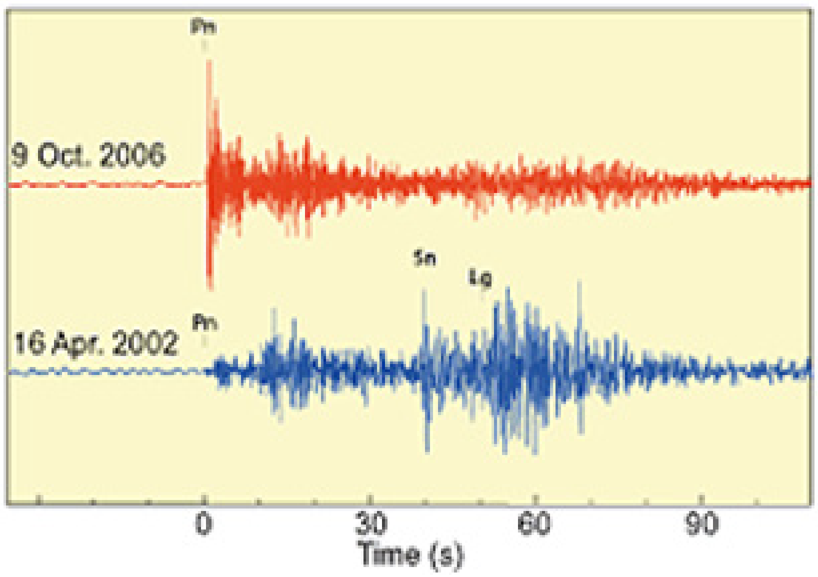

Figure 1. Seismograms for the 2006 nuclear test (top) and for an earlier earthquake (bottom) in the same region (CTBTO-Testing, 2012).[7]

dicating that North Korea is excavating a new tunnel for nuclear testing near the previous test sites (Lewis, 2015).[11] We must omit certain natural events such as an asteroid impact, volcanic eruptions, mine collapse, landslide and tornados. Second, we must also omit certain human-caused events such as an industrial accident, or routine mining. This leaves three possibilities to investigate, a conventional explosion, a nuclear explosion or an earthquake. Of note, in underground nuclear blasts the dominate wave is the P wave while the dominate wave in earthquakes is the S wave.

WHY IT IS NOT AN EARTHQUAKE

North Korea does not sit on a high prone earthquake area and the particular area where the three events occurred has experienced no earthquakes on record since 2003. The North Korean peninsula is mostly granite and gneiss Precambrian rocks and is in a safe zone beyond the Ring of Fire. There are historic records of seismic events in the southeastern peninsula. The first reported earthquake was in A.D. 2 and the most destructive earthquake in Korea was in A.D. 779 (National Institute of Korean History, 1993).[13] Inchon had the first seismometer installed in Inchon in 1905. A depiction of pre-1905 earthquakes on the Korean Peninsula are on Figure 3.

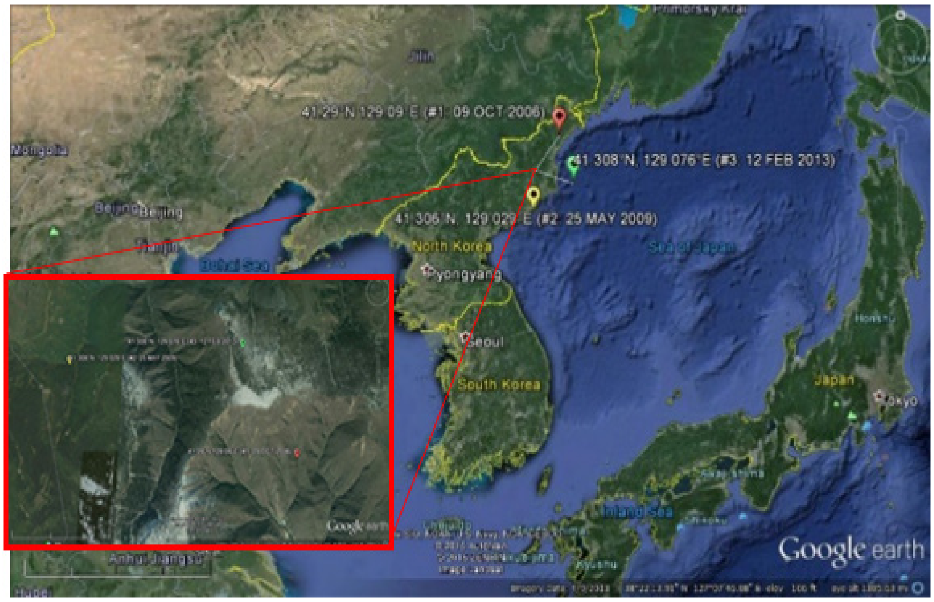

Figure 2. Location of seismic events on Korean Peninsula.

Duration (years)	Location	Number of Earthquake					Total No.
		1.0⊕~2.0	2.0~3.0	3.0~4.0	4.0~5.0	5.0~6.0	
18 (1926~1943)	The Korean Peninsula (excl. sea)	NA⊗	40 (44.0%)	29 (31.9%)	20 (22.0%)	2 (2.2%)	91
18 (1926~1943)	The Korean Peninsula (excl. sea)	4 (0.4%)	686 (68.7%)	270 (27.0%)	34 (3.4%)	5 (0.5%)	999
18 (1926~1943)	The Korean Peninsula (excl. sea)	3 (0.5%)	415 (71.4%)	151 (26.0%)	20 (22.0%)	3 (0.5%)	581
18 (1926~1943)	The Southern part of the Korean Peninsula (excl. sea)	3 (0.6%)	369 (76.1%)	105 (21.6%)	6 (1.2)	2 (0.4%)	485
18 (1926~1943)	The Southern part of the Korean Peninsula (excl. sea)	63 (9.0%)	501(71.6%)	128 (18.3%)	8 (1.1)	0 (0.0%)	700

Table 3. Number of earthquakes depending on the earthquake magnitude for each dataset (Jung-Woo Kim, 2015).[10]

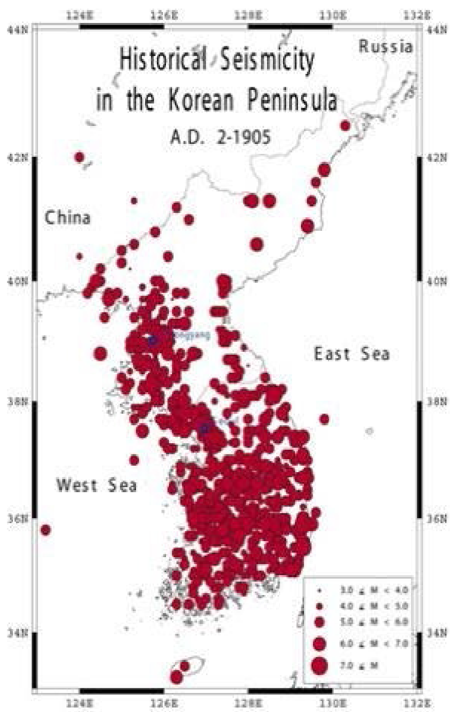

Figure 3. Historical Seismicity in the Korean Peninsula A.D. 2-1905.

Historically, the area where North Korea tested their nuclear devices is not prone to earthquakes. Once we entered the 20th century and developed scientific equipment to measure earthquakes a more precise historical record for the whole peninsula comes into focus. In a 35-year period from, 1978-2012 in Table 3, North Korea had three, 4.0-5.0 earthquake, events and one, 5.0-6.0 event. The chance that three greater than 4.0 magnitude events occurred at roughly the same point of the earth over a seven-year period leaves doubt on the earthquake side.

WHY IT IS A NUCLEAR EVENT

In 1988, the former Soviet Union and the United States signed a bilateral agreement in which each country would monitor each other's underground nuclear explosions. Underground nuclear testing started in the 1950s and seismic observations were the initial methods used to verify the location and strength of these events. These Joint Verification Experiments (JVEs) would permit hydrodynamic measurements close to the explosions in order to provide accurate yield estimates. The data would then provide a method to determine yields of other nuclear detonations through seismic measurements at long distances. Teleseismic pertains to data measured from distances greater than 1000 kilometers. When the Threshold Test Ban Treaty (TTBT) went into effect in 1976, the United States relied on teleseismic data to monitor the Soviet Union's compliance of the 150-kiloton (kt) limit

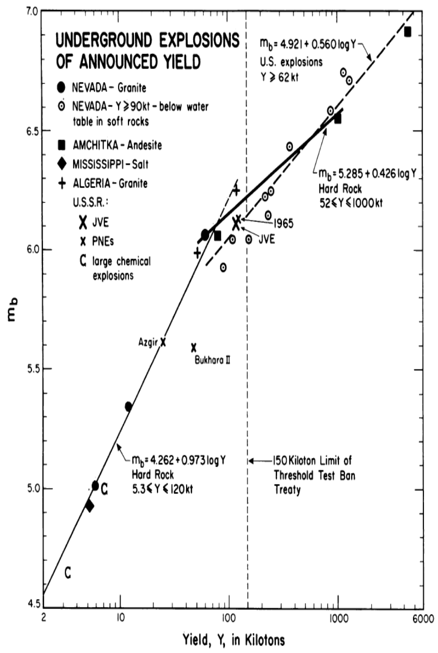

Figure 4. Underground explosions of announced yield in Hard Rock.

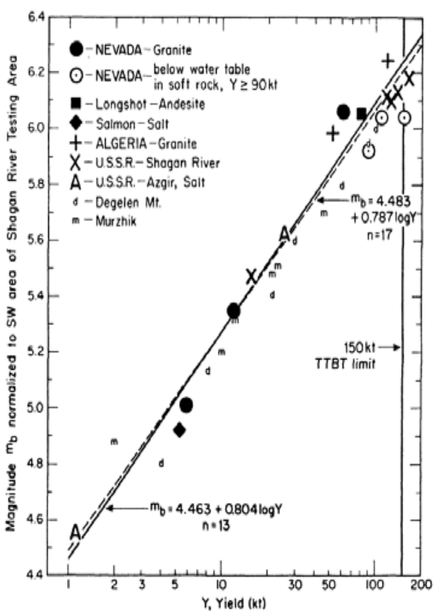

Figure 5. Yield estimation in Salt. (Sykes L. R., 1991).[15]

set forth in the TTBT agreement. The further agreement in 1988 set the conditions that further yields of the JVEs would be between 100 and 150 kt. One of the tested evaluation methods involved seismic monitoring. They found that seismic technology is an efficient way to detect a suspected nuclear explosion. Since seismic waves travel fast, the data collection period can range from seconds to ten minutes.

The Comprehensive Nuclear-Test-Ban Treaty (CTBT) uses Seismic monitoring to monitor compliance with the Treaty.

Figures 4. and 5. come from the JVEs in 1988. Figure 4. covers underground nuclear explosions in hard rock, while Figure 5. covers underground nuclear explosions in salt. If you select the Magnitude (m_b), which lies on the y-axis and go over to the meet the line it will then correspond to the x-axis which is the nuclear yield in kilotons.

Nuclear tests relating to North Korea seismic data will use the data in Table 1. and apply it to Figure 4. since it lies in a hard rock area. This data lines up well with the CTBTO results in Table 2.

Date	Magnitude, m_b	Yield
09 Oct 2006	4.1	Less than 2 kt
25 MAY 2009	4.5	Around 2 kt
12 FEB 2013	5.1	7 kt

Table 4. Interpretation of graphical representation of North Korea nuclear tests.

THE BACK OF THE ENVELOPE CALCULATION

An equation to find the yield strength based upon the magnitude is derivable from Figure 4. and 5. (Carey, 2015).[1] The log used in Figures 4. and 5. are base-10. However, one issue to observe is the area of the functions on Figure 4. where they overlap when $6.0160 \le M_b \le 6.2850$ (or equivalently when $52 \le Y \le 120$). One can write equations for the slope function to provide the answer to yield by simply plugging in the magnitude for m_b and solving for Y. The equations for Hard Rock (Figure 4.):

Yield (in kilotons) when ($m_b \le 6.285$) $=10^{((m_b - 4.262)/0.973)}$

Yield (in kilotons) when ($m_b \le 6.016$) $=10^{((m_b - 5.285)/0.426)}$

When we apply these formulas to the North Korea seismic data (Table 5), we end up with numbers that are closely consistent with the CTBTO data in Table 2. The inversions for Salt (Figure 5.).

Yield (in kilotons) $=10^{((m_b - 4.463)/0.804)}$

Date	Magnitude, m_b	Yield
09 Oct 2006	4.1	0.68 kt
25 MAY 2009	4.5	1.84 kt
12 FEB 2013	5.1	7.26 kt

Table 5. Inversions of formulas from Figure 4.

These calculations backed up by research from the JVEs demonstrate that North Korea was able to detonate a nuclear device. The scientific community considers the first test, a possible fizzle event, where the test did not meet the expected yield (Nature, 2006).[14]

WHY IT IS NOT A CONVENTIONAL EXPLOSION

Now that we know the nuclear equivalent of the charge from the previous research, we can look at how much explosives North Korea would have to load in an underground mine to deliver the same kiloton type events. As an example, before the Trinity nuclear bomb test, the scientists needed to calibrate the instruments and test out their procedures before the actual nuclear detonation.

One of the tests involved the detonation of 100 tons of Trinitrotoluene (TNT). Figure 6. depicts what 100 tons of stacked TNT looks like. This was a relatively square structure so the distance across is the same distance deep. Now to make this equivalent to 7 kilotons, there would have to be approximately 35 of these stacks underground. A total of 70 stacks are not needed because a nuclear explosion does not have the same gas generation of a conventional explosion. As an example, a 4 kiloton TNT equivalent charge provides the same blast and shock effect of a 8 kiloton nuclear detonation (Defense Nuclear Agency, 1986).[8] That is for TNT, which would be a large monetary cost, but making a TNT equivalent with ammonium nitrate-fuel oil (ANFO) would take up an even larger area. If ANFO were the explosive of choice, then the volume would be even larger when adjusting for TNT equivalency and density of ANFO vs TNT.

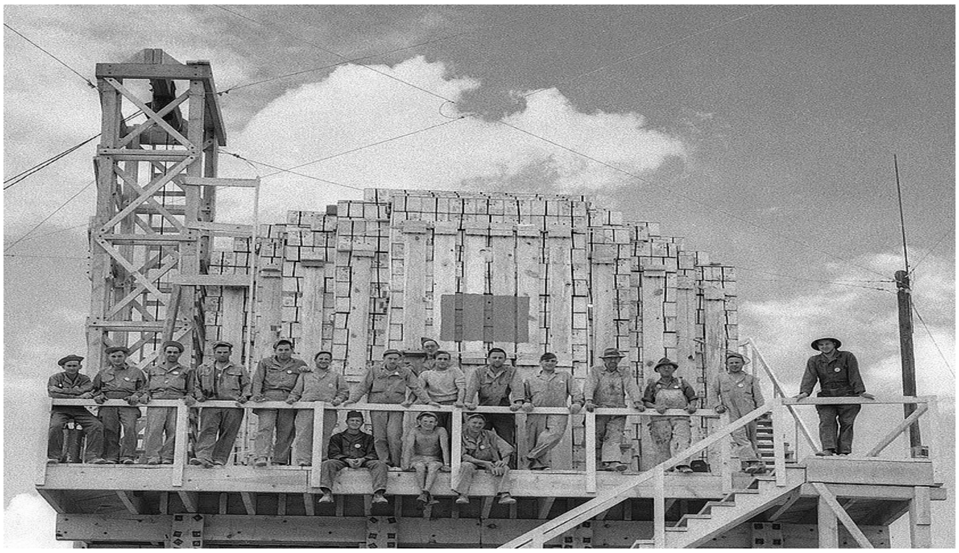

Figure 6. 100 Ton Test (Los Alamos National Laboratory, 1944).[12]

The North Korean testing area has the focus of the international community in terms of satellite observation. Either of these scenarios would leave a large throughput footprint of explosives that satellite imagery would pick up. In addition there would have to be a large amount of spoil removed from the underground facility to make room for the large amount of explosives. Since there has not been any evidence of the explosives throughput, it eliminates the possibility of a conventional TNT type explosion.

THE SHORT HISTORY AND FUTURE FOR TREATY VERIFICATION

The first International Monitoring System team met in August of 1997 to lay out a rapid pathway to build a monitoring network and adhere to the Comprehensive Nuclear-Test-Ban Treaty's (CTBT) stringent specifications. Now they are more than 85 percent complete, with 275 worldwide IMS monitoring stations, to include certification of 11 radionuclide laboratories and 14 noble gas systems. Overall, they will use four different technologies to carry out their duties (CTBTO-Background, 2012).[3]

The IMS will use three waveform technologies. There will be 170 seismological stations to detect and locate underground nuclear explosions and differentiate natural (earthquakes) and human-made (mining explosions) events. There will be 11 hydroacoustic stations with 6 underwater hydrophone and 5 T-phase stations located onshore and on small islands. These will monitor underwater acoustic waves in the oceans. The last waveform technology will be 60 infrasound stations designed to detect low frequency sound waves within the atmosphere. In addition, there will be 80 radionuclide stations that will analyze air samples for radioactive particles. These will complement an existing 16 radionuclide laboratories (CTBTO-IMS, 2012).[5]

CONCLUSIONS

Using the formulas derived from the logarithmic plots from the United States and Soviet Union Joint Verification Experiments it is possible to perform a back of the envelope calculation to determine the yield from a detonation of a nuclear device. These are dependent upon the type of geological formation where the detonation occurs. There is an area of concern when looking at hard rock around the level 6 magnitude, but any country testing towards that level is wasting the valuable fissile resource when magnitudes around level 5 provide proof to the world that they are a nuclear power.

FUTURE WORK

This paper rests on analysis of Figure 4., which came from Comparison of seismic and hydrodynamic yield determinations for the Soviet joint verification experiment of 1988. This publication search was formidable and I could only find one other publication involving test results from nuclear detonations in salt. Based upon these two publications, there are obviously additional geological related testing parameters to find. If the additional publications show the same scaling functions of the testing, then a back of the envelope formula for each geological area should be a product.

Additional areas to research involve data from large underground explosions. In Dowding's book, Blast Vibration Monitoring and Control (Dowding, 1985)[9] there is a comparison between a 15 lb. explosive charge, a 1-megaton nuclear explosion and the El Centro, California earthquake from 18 May 1940. (The book incorrectly lists the date time group as 18 May, 1949) which had a magnitude of 6.9MW.

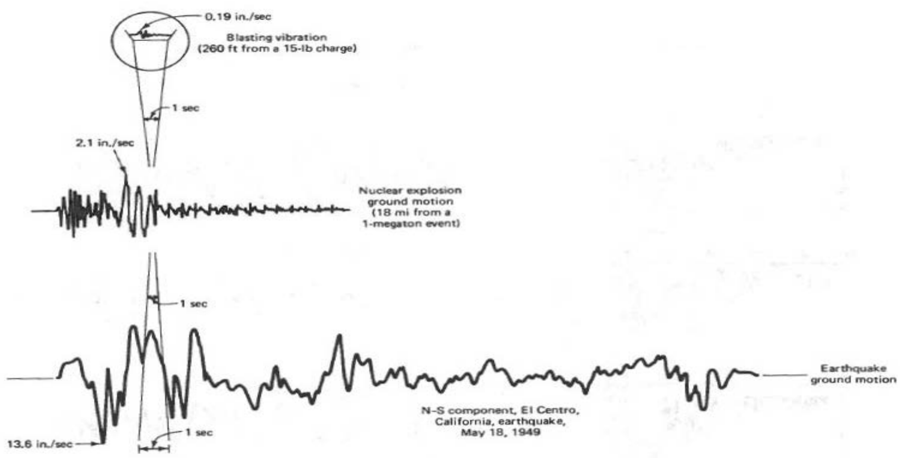

Figure 7. Excerpt of Blasting vibration compared to nuclear and earthquake motions.

These three comparisons are not close enough to show how they are different because there is no scale applied to the graphs. A recommended comparison would involve incorporating a lower kiloton underground nuclear test in hard rock from some of the JVEs and comparing it to a 5-6 magnitude earthquake. The problem with fixing the explosives test is finding a large-scale test that is underground

In 1985 and 1987, the Defense Nuclear Agency conducted two tests, Minor Scale and Misty Picture, respectively, at the Permanent High Explosive Test Station at White Sands Missile Range (WSMR), New Mexico. (Ciphar, 1988)[2] Each of these tests involved the open-air detonation of 4 kilotons of ANFO. The test itself was for testing design systems primarily related to a simulated nuclear overpressure environments. This explosive test would help meet the kiloton requirement, but since it was not underground, the energy could not fully couple to the ground. Article Reviewer: Braden Lusk, Ph.D., P.E. University of Kentucky, College of Engineering.

Figure 8. Minor Scale Explosion.[8]

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Biography

MAJ Carey is a FA52 serving as the Deputy for the Huron Lynx program, Combating Terrorism Division, Counter WMD Technology Department, R & D Directorate, Defense Threat Reduction Agency. His previous assignments include: Weapons Effects Officer, Physical Vulnerability Division, DIA; EOD/WMD Counterterrorism Officer, JITF-CT, DIA; Commander, 737th Ordnance Company (EOD); EOD Operations Officer, Tech Escort Unit; Platoon Leader, 529th Ordnance Company; Team Chief, 55th Ordnance Company (WMD); Response NCO, 749th Ordnance Company (EOD); EOD Team Leader, 8th Ordnance Company (EOD); EOD Sergeant, 149th Ordnance Detachment (EOD); Heavy Anti-Armor Infantryman, 2-22 Infantry. He is a graduate of ILE and the Joint and Combined Warfighting School. He earned a M.S. in Mechanical Engineering with a Specialization in Explosives Engineering from the New Mexico Institute of Mining and Technology.

Army Nuclear Weapon Effects Program (ANWEP)

Mr. Matthew Jackson
United States Army Nuclear and Countering WMD Agency

INTRODUCTION

Over the last year the US Army Nuclear & CWMD Agency has been developing the successor to the Nuclear Weapon Effects Database System (NWEDS), with a computational library we call the Army Nuclear Weapon Effects Program (ANWEP). ANWEP will be replacing a code that has been used for over thirty years by the Army for both offense-oriented theater targeting and defensive (preclusion) targeting (where should we position friendly forces to minimize risk to prompt effects?). This article will discuss the motivation behind replacing NWEDS, the capabilities of NWEDS' replacement, ANWEP, and examples of final products which can be assembled in a matter of minutes using the code.

Basic Targeting Calculations in ANWEP

Before discussing the motivation behind replacing NWEDS, one must first become acquainted with the basics of calculating the probability of damaging a target to some level (for example, severe damage to a wood frame building). In order to do this, one must compute a variable called the probability of damage (PD) (Equation 1). The PD quantifies both the uncertainty in the weapon landing where one expects, as well as the uncertainty in the target being damaged given some damage mechanism (blast, thermal, or prompt radiation) at some radial and vertical offset from the desired ground zero (DGZ).

The PD can be expressed as the product of the probability density function describing weapon error, ρ(r,z), and the probability of damaging a target given one or more damage mechanisms, P_d (r,z), where r and z represent the radial and HOB offset from the DGZ. By solving equation 1, ANWEP can compute a wide range of useful metrics, from the classic effects circles that codes like NWEDS produce, to full PD maps which can be incorporated with a variety of GIS tools to perform more detailed analysis. As we will see later, NWEDS is unable to directly compute equation 1., and instead relies on a series of approximations to calculate something similar.

$$P_d(r,z)=\iint P_d(r,z)*\rho(r,z)drdz$$

Equation 1.

Building on Equation 1, we can also define probability distributions for multiple weapons or multiple effects, as seen in Equation 2. This makes ANWEP one of the few fast running prompt effects codes that can model not only combined injury due to multiple environmental effects (i.e. personnel injured by a combination of blast, thermal, and prompt radiation) and multiple weapons. One limitation of Equation 2. is that synergistic effects are not accounted for.

$$PD_{Total}=1-\prod^{n}_{i=1}(1-PD_i(r,z))$$

Equation 2.

History and Limitations of NWEDS

NWEDS was originally developed in the early 1980s, and while the user interface has improved over the years, the underlying algorithms in the code have essentially remained the same. In the 1980s computers were very limited – a desktop computer at the time might have a clock speed of 1-2 MHz, and possess 64 KB of RAM, with a hard drive that could hold a few MB of data. Needless to say, memory and processor speed were a major constraint when NWEDS was developed. As such, many tradeoffs were made in NWEDS, both in terms of storage and to speed up calculation time. Perhaps the most impactful choice made was that NWEDS would only store data in the nodes where you needed results.

Army Doctrine establishes five probabilities that are needed for theater targeting:

- 50% - Offense-Oriented Target
- 10% - Least Separation Distance (Safety Calculation)
- 5% - Collateral Damage Distance / Emergency Risk (Safety Calculation)
- 2.5% - Moderate Risk (Safety Calculation)
- 1% - Negligible Risk (Safety Calculation)

Targets in NWEDS could then essentially be broken into two categories:

- Offensive Oriented Targets (Calculations were only defined at 50% probability of damage (PD))
- Preclusion Targets (Calculations were defined for one or more of 1%, 2.5%, 5%, 10% PD)

To further complicate matters, some targets were only of concern in a tactical yield range (<100 kt), and as such, only enough data was populated in the database to cover this yield range. If one tried to apply the data using yields outside those bounds, NWEDS does not even extrapolate the values – meaning that at high yields one could potentially underestimate damage by a significant margin, while grossly overestimating damage at low yields. In one particular case this resulted in NWEDS over-predicting the range to effect for a target by a factor of 15. The result of this storage strategy was that NWEDS became a database of discrete, unrelated, calculations.

From a database management perspective, the discrete values also become much more difficult to maintain than a few coefficients for the relevant probability distribution. As an example, our most up-to-date radiation criteria for fatal injury is in the form of a probit equation, which is simply a linear fit to the z value vs log(Dose); by specifying two floating point values, a probit equation can be used to define the radiation dose required for any probability. Yet because NWEDS is a discrete database, values from the probit equation were stored independently for five different probabilities of damage (0.5, 0.1, 0.05, 0.025, and 0.01). To make matters worse, although NWEDS scales the free-field radiation output from a weapon by a series of transmission factors, to account for the protection afforded by personnel inside vehicles or structures, NWEDS still requires that the radiation thresholds be manually linked to each and every environment in which personnel are located. This represents hundreds of unnecessary nodes in the database that must be manually maintained. It was quite understandable then that the NWEDS database was rarely updated.

If the discrete values only affected the database size, it would be a minor issue. Yet the more insidious influence of these discrete values was lies in how they affect the accuracy of NWEDS calculations. For many years NWEDS has been one of the few prompt effects codes that was capable of calculating combined injury to personnel (i.e. injury due to the combined effects of blast, thermal, and prompt radiation). Despite the feature being so well known, it was one of the more poorly documented features in NWEDS. As it turns out, within NWEDS there is a graph entitled “COMBINE” which was used to compute an effective combined radius of damage given two other damage radii (blast and radiation, for example). This graph was ultimately derived from DNA 4809F: FM101-31/AP550 Modification Development Program for the Coordination of Results in Common Targeting Situations. Figure 1. depicts the graph shown on page 94 of the DNA report, and relates the combined damage radius for a 50% probability (r_{50}) given two separate r_{50} effects. For example, if the r_{50} for prompt radiation is 620 m, and the blast RD50 is 640 m, the combined r_{50} would be 700 meters, or an increase of approximately 9%.

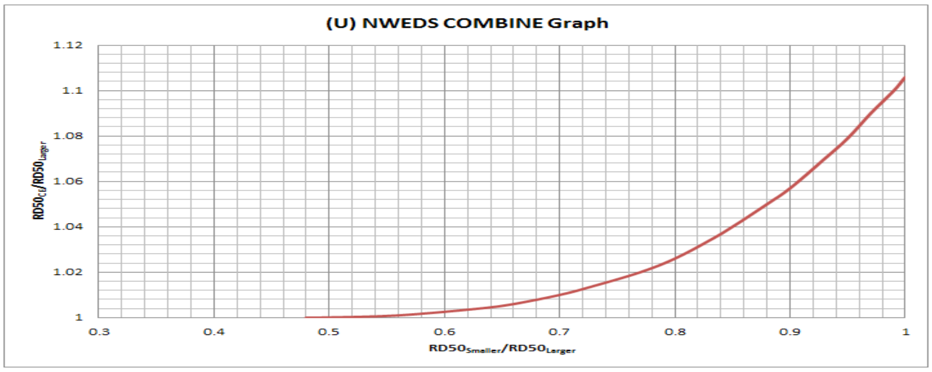

Figure 1. Combined Effects Radius Graph. (DNA 4809F Figure 10., Page 94)

The underlying assumption for the graph in Figure 1. is that the underlying distribution for r_{50}s have a damage sigma of 0.2 (or sometimes referred to as the 20% variability curve). The report even states that “thermal radiation is not considered as a damage mechanism by either FM101-31 or AP550 due to the extreme variability of its effects”,[1](Vitello, A.P., Ulrich, R.M.(1978) yet in later years, it became common practice to use the graph shown in Figure 1. as the mechanism to combine blast, thermal, and radiation effects. Even more disconcerting, this was later applied to other probabilities, where the graph was not valid at all.

The appropriate methodology for combining probabilities due to multiple damage mechanisms would have been to determine the proper underlying distribution for each damage mechanism (blast, thermal, or radiation), integrate them with the weapon error found as shown in Equation 1., and then finally combine the individual probabilities for blast, thermal, and radiation using Equation 2. Why didn’t NWEDS do this? Because data in NWEDS was stored discretely, the code had no way of forming a probability distribution. This shortcoming is also seen in the fractional coverage calculations found in NWEDS. Once again, the code assumed that the damage sigma for every target and damage level is 0.2, when performing fractional coverage calculations. This impacted every single calculation found in the Army FM 101-31 and the JP 3-12 series of publications. Over the last few years USANCA has discovered numerous instances where this 0.2 damage sigma assumption proved invalid.

Almost all of NWEDS’ limitations can be attributed to the database consisting of discrete values. USANCA weighed the option of modifying NWEDS to support continuous distributions, but ultimately determined that to do so would essentially require an entire rewrite of the code. It would have been necessary to replace every database entry with new probability distributions. Almost all of the calculation routines would have to be updated as well. Meanwhile, NWEDS was optimized to perform these discrete calculations, and would have required extensive class restructuring to update the code to use continuous distributions. In short, updating NWEDS would have taken much more effort than starting fresh with a new code base.

Moving from a Discrete Dataset to Continuous Distributions

As mentioned previously, one of the primary shortcomings of NWEDS was that it did not have the capacity to link its discrete datasets. Which meant simple probit equations had to be broken down into single value graphs containing individual points along the curve. One of the first issues to resolve during the development of ANWEP was constructing a set of probability distributions that could encapsulate all the necessary probability distributions. Ultimately, seven probability distributions were identified for inclusion into ANWEP. These distributions are used to define $Pd(r,z)$ found in Equation 1.

* Lognormal in Ground Range Space (Currently unused in ANWEP, but used in NWEDS for development of PDCALC personnel tables)

* Lognormal in Slant Range Space (All structure response graphs in ANWEP)

* Lognormal in Phenomenology Space (Some thermal and blast criteria)

* Normal in Phenomenology Space (Currently unused)

* Probit Equation (Most radiation, thermal, and blast criteria for personnel in the open)

* VNTK Scaling (Used for some structure response criteria)

* EM-1 Chapter 17 Lognormal Scaling (a lognormal distribution developed for use with EM-1 Chapter 17 cubic fits to Army field equipment survivability criteria)

After making these changes, the NWEDS database of roughly 600 graphs was reduced in ANWEP to roughly 125. The integration of PDCALC into ANWEP had the added benefit of greatly expanding our target set – within ANWEP we can now readily ingest VNTKs into PDCALC and use those for evaluation.

Targets in ANWEP

In ANWEP, the definition of a "target" has been expanded. In the past a target represented one set of damage criteria for an entire object, which limited our ability to tweak calculations based on population profiles inside structures, or simply to compute average effects for some urban environment. Within ANWEP, every target can be broken into one or more "blocks". The easiest example to visualize is a city block, where there may be multiple building types. In NWEDS, for example, assumed every person inside a city was located inside the basement of an apartment complex, which led to drastically underestimating the true casualty count in a city. Within ANWEP one could instead define the urban landscape as 50% multi-story wall bearing buildings, 25% wood frame buildings, and 25% multi-story steel frame buildings, and from there, compute the average probability of damage based on the given population profile. This also gives one the flexibility to adjust building distribution based on intel specific to a given site.

Within the NWEDS database, a target contained many duplicate damage calculations. For example, if one wanted to define a calculation for 50% fatal injury in wood frame buildings and in the open, NWEDS required the same value of 410 cGy be separately defined for each personnel environment. However in ANWEP, global environment calculations exist, so that the probit describing fatal injury is linked once, and is then automatically pulled into all personnel fatal injury calculations. The code also supports overriding the global thresholds for a particular target. This replaced hundreds of duplicate damage calculations found in NWEDS with a single set of six global calculations.

Enhancements to Environments in ANWEP

Since ANWEP can connect to GIS tools to retrieve data like elevation, ANWEP can use that data to adjust blast and radiation environments as a function of altitude. Figure 2. shows a typical example of the changes that occur in the radiation spectrum at a 4 km elevation vs sea level. Figure 3. shows the change in blast as a function of ground elevation. In the vast majority of scenarios these changes will be small (a few percent at most in overpressure or radiation – even less when placed in a lognormal distribution), but the code accounts for this.

To further enhance visibility calculations, ANWEP also calculates the fireball rise using formulas found in EM-1 and the ATR 6 technical manual. Our visibility calculations also treat the radiation visibility calculations differently (prompt radiation is released at HOB, while fission product gammas are released as the fireball rises.

GIS Integration

To avoid expensive licensing requirements that go hand in hand

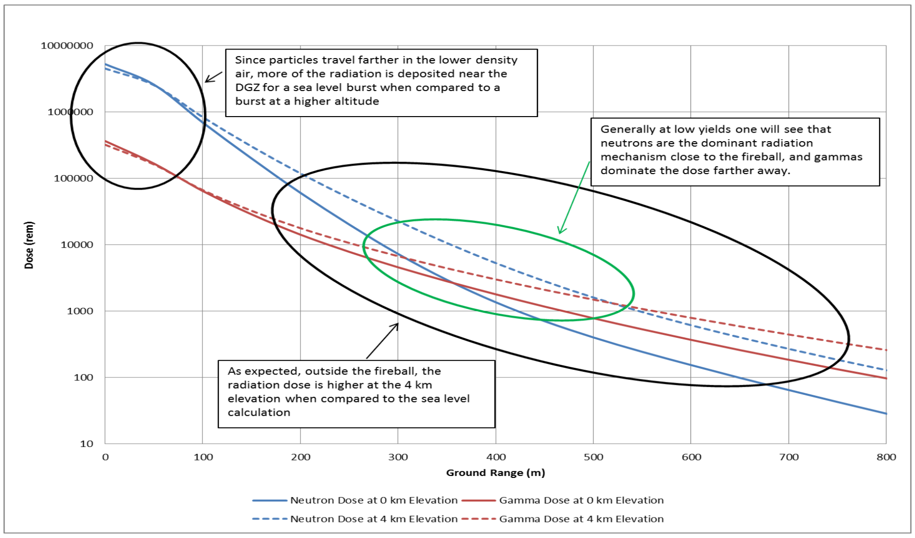

Figure 2. Radiation Dose vs Ground Range (1kt)].

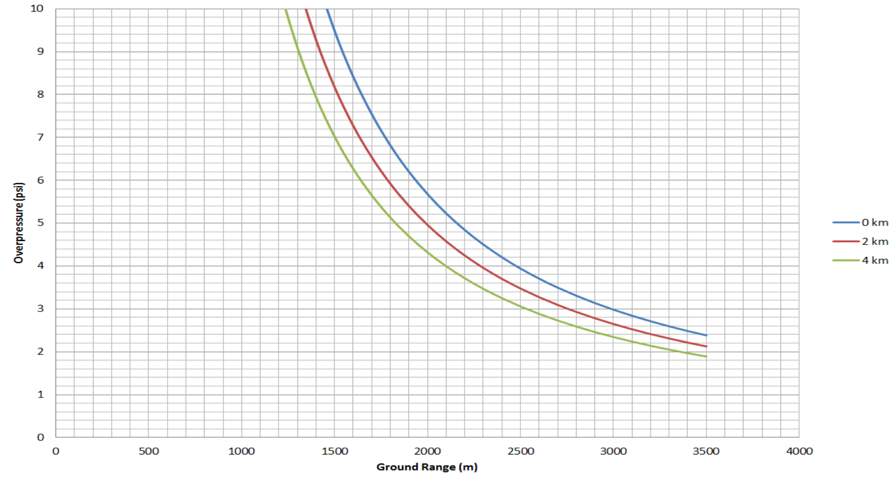

Figure 3. Overpressure vs Ground Range (100kt)].

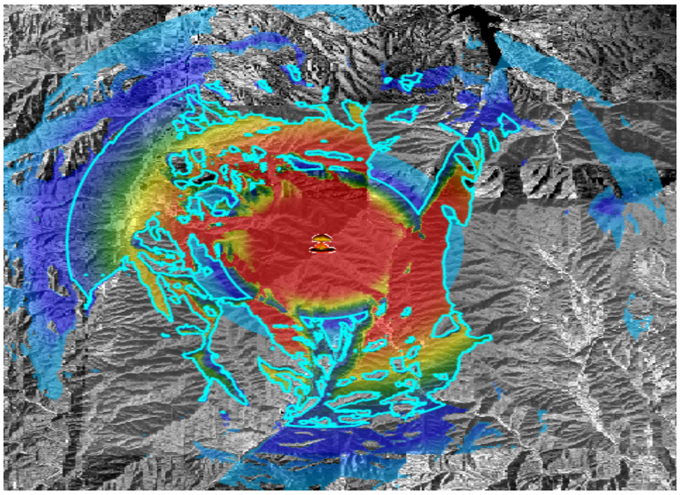

Figure 4. CDD to Personnel in the Open.

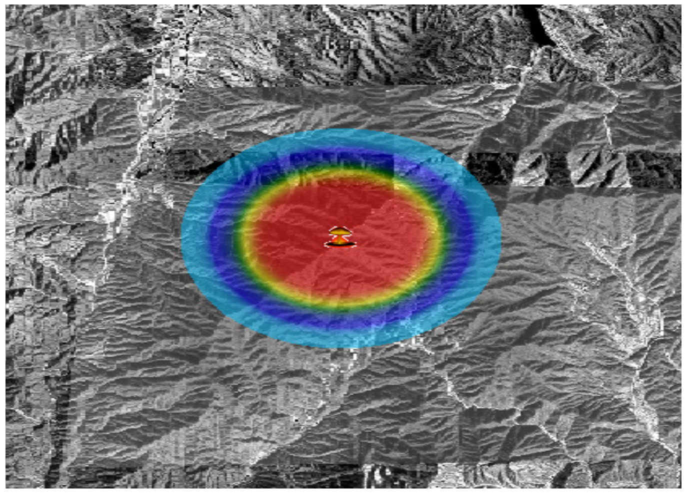

Figure 5. Probability of Damage due to Blast Effects.

with most commercial GIS libraries, ANWEP utilizes several open source tools which have proven more than adequate for our requirements:

* Quantum GIS – a standalone GIS system under active development – very popular with the Linux community.

* Grass GIS – yet another standalone GIS system, with an extensive command line interface. GRASS GIS was originally funded by NGA in the early 1990s.

* GDAL – a powerful open source raster/vector manipulation library – both GRASS and Quantum GIS use GDAL underneath the hood for their calculations.

ANWEP Calculations

While ANWEP's engine allows for great flexibility, the code is optimized to perform standard preclusion targeting metrics. The code scales very well with multiple processors, and generally provides results within two minutes on a standard PC. Some of examples of the calculations possible in ANWEP include:

* Tabular Calculations

o Range to Probability of Damage (PD) – this allows ANWEP users to produce the typical NWEDS tabular output, where the user gets the range corresponding to a static probability of damage

o Fractional Coverage Calculations – this calculation helps answer the question, "what fraction of personnel or materiel will be damaged to a given level?" Currently restricted to circular targets for tabular calculations.

* GIS Calculations:

o Probability Map – this simply builds a raster file showing the probability of damage for a given damage level, target, and weapon. When linked with a GIS tool, ANWEP can compute the visibility range and adjust the probability map to account for areas which are excluded from line of sight.

o Safety Contours – this generates safety contours (not necessarily circles) for a given safety calculation. Like the probability map, will account for line of sight if linked to a GIS tool and the proper elevation data.

o STRIKWARN Message – automates the process of building a STRIKWARN message, producing both the message and a series of shapefiles showing the safety contours for the given weapon.

o Population Calculation – automates the process of calculating casualties for a given location. This requires connection to a GIS tool and the proper LANDSCAN data linked to the code.

o Fractional Coverage calculations

* ANWEP can calculate the fractional coverage of a weapon on a target defined via shapefile (a recent example included calculating the fraction of aircraft hangars damaged).

ANWEP Calculation Example

To illustrate the analysis capabilities of ANWEP, two examples are provided. The first involves calculating the collateral damage distance (CDD) for serious injury to personnel in the open, which is the contour that forms the edge out of which there is less than a 5% incidence of serious injury, with a 99% assurance buffer. Figure 4. shows the results of this scenario. The light blue lines correspond to the edge of the CDD region for this scenario. The probability map underneath provides a quick overview of the probability of damage, where light blue is very low (<1%), and red is very high (>75%).

ANWEP also supports viewing the individual effects (blast, thermal, prompt radiation) for a given scenario. In Figure 5. we see the blast probability map. ANWEP does not currently account for line of sight when computing blast environments, and as such you get the classic weapon effect circle. If ANWEP did not perform line of sight calculations at all, all individual weapon effects would be circles.

Figure 6. shows the probability of damage due to prompt radiation. Numerous areas are shielded due to line of sight and have a probability at or nearing zero. Figure 7. shows a similar plot for the thermal effects. If one looks closely at the area to the left of the weapon DGZ, one will note the differences in the radiation visible region and the thermal visible region. This is

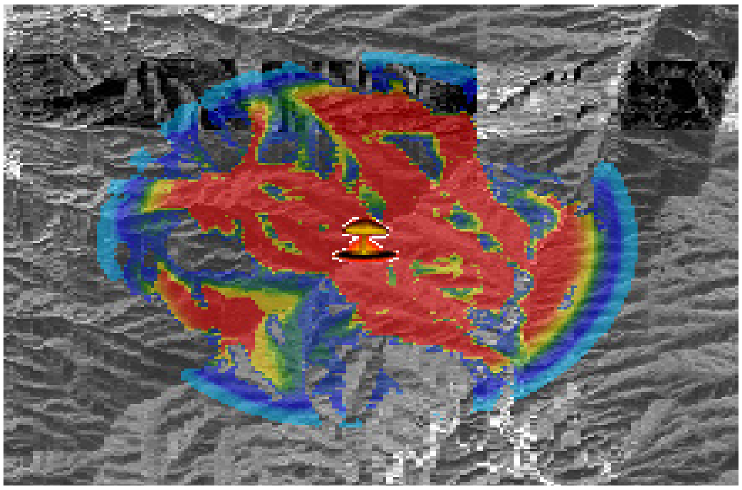

Figure 6. Probability of Damage due to Radiation Effects.

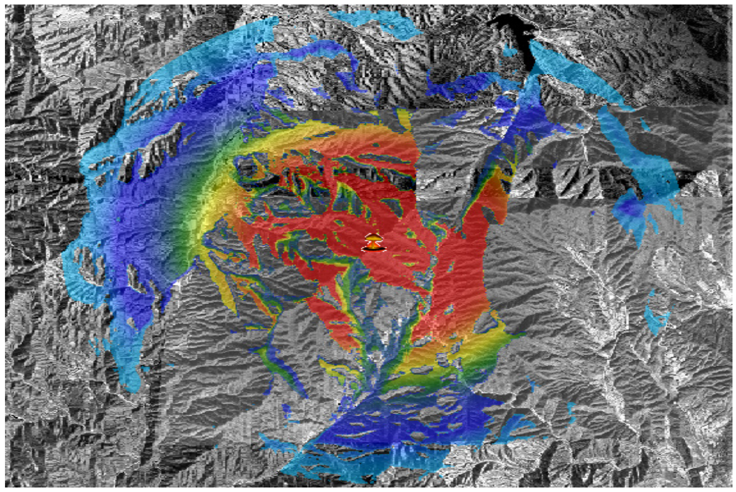

Figure 7. Probability of Damage due to Thermal Effects.

because the bulk of the radiation dose is from prompt or delayed neutrons/gammas, and fission product gammas only account for a very small amount. As such the visibility map at the 20m HOB dominates the radiation solution. Meanwhile, for thermal, as the fireball rises more of the region is visible, resulting in fewer line of sight gaps in the same area subtended by the radiation region.

A second example was a damage assessment calculation on an airfield. This demonstrates the ability of ANWEP to take a shapefile containing multiple targets (in this case, an aircraft), and compute the probability of damaging each individual aircraft. As seen in figure 8., the code not only computes the probability of damage to each target, but color codes them appropriately as well.

Future Plans

Version 1.0 of ANWEP is undergoing final testing this month (January 2016). Future releases in the 1.x series will be focused on bug fixes, while version 2.0 will be focused on adding fallout calculation capabilities to the code using HPAC, and more performance improvements. As USANCA continues to advance ANWEP, we continue to work with DTRA to add (where relevant) these features to their eNWEDS code.

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Biography

Matthew Jackson is a Nuclear Engineer serving as a Nuclear Effects Modeler at the U.S. Army Nuclear and CWMD Agency in Fort Belvoir, VA. He has spent the last five years at USANCA developing improved nuclear effects models for theater nuclear targeting applications. Mr. Jackson has a B.S in Nuclear Engineering from Texas A&M University, and a M.S. in Computational Engineering from the University of Tennessee - Chattanooga. His email address is matthew.r.jackson3.civ@mail.mil.

Figure 8. Probability of Damaging Aircraft.

The Return Of Weapons Of Mass Destruction Elimination (WMD-E) Operations

Bilateral (US/DEU) Re-investigation of the Elimination Mission Set

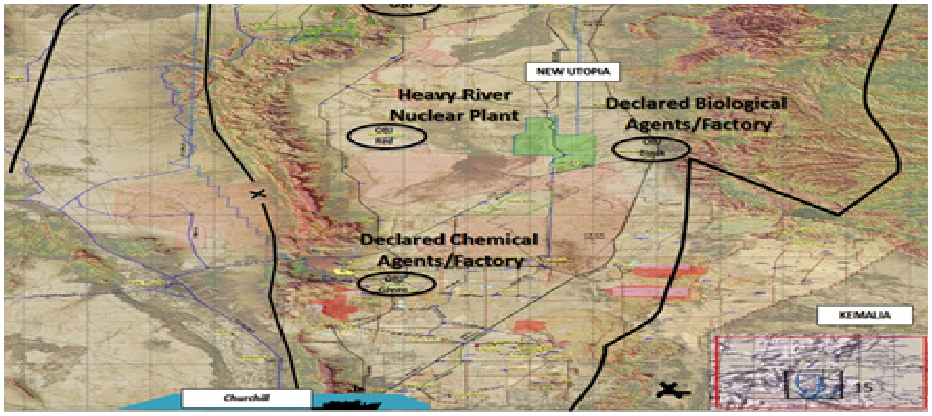
LTC Daniel P. Laurelli
United States Army Nuclear and Countering WMD Agency

LTC Michael Petrunyak
United States Army Nuclear and Countering WMD Agency

In September teams from the United States Army and Germany Army converged at USANCA on Fort Belvoir, VA to discuss WMD Elimination/ Disablement (WMD-E) and participate in a Table Top Exercise (TTX). Planning for the TTX began the year prior during the German / American Army Staff Talks in Potsdam, Germany when both Armies in the CBRN Working Group agreed on three Agreed to Actions (ATAs). The first ATA was focused on increased CBRN partnership between existing Bundeswehr and US Army Europe based CBRN forces, the second involved exploring CBRN Instructor Exchange between the CBRN School in Fort Leonard Wood and the CBRN School in Sonthofen, Germany, and the final was to explore increased cooperation in the area of WMD Disablement. The catalyst for the third ATA was the recent success of the 2014 Organization for the Prohibition of Chemical Weapons (OPCW) mission that eliminated declared Syrian chemical weapons.

Background: Valkyrie Scenario Table Top Exercise (TTX)

The setting for the TTX is in the year 2020 as the newly formed country of New Utopia is recovering from its recent civil war and reaching out to the international community for humanitarian assistance, Security and Stability, and WMD Elimination assistance. The former Transian Government of New Utopia was a signatory of the Chemical Weapons Convention (CWC) but were unable to meet compliance before the civil war.



Area of Operations (Transia).

Transia maintained a robust chemical weapons program, with some covert and overt facilities as well as others mixed with commercial "dual use" facilities. Additionally, the Transian Government had a research and production capability for biological agents and weapons with some facilities sharing space with local hospitals and medical facilities. There was an additional radiological threat presented by the Heavy River Nuclear Power Facility. While operational for over 30 years, the facility went to an inactive and off-line status following the 2010 Fukushima accident but still stored a significant amount of radiological associated materials of concern.

Organizations participating in the TTX included the Bundeswehr CBRN Defense Command, Bundeswehr EOD and Special Forces, USANCA, 20th CBRNE Command, the 48th Chemical Brigade, the Joint Program Manager (JPM) for Elimination, JPM Radiological Defense, Edgewood Chemical Biological Center (ECBC) and the Defense Threat Reduction Agency. The group broke out into four multinational teams as follows:

- Working Group 1 (Locate and identify)
- Working Group 2 (Control and Secure)
- Working Group 3: (Characterize and Attribute)
- Working Group 4 (Defeat, Disable, Dispose/Destroy)

The TTX was separated into three separate scenarios (Chemical Weapons, Biological Weapons, and Radiological Threat) and collaborated collectively on their facilitated analysis and recommendations over the two day exercise. Each Scenario presented unique challenges to the WMD-E mission.

Before the two day TTX, participants visited Edgewood Arsenal and were briefed on US capabilities for

Elimination/Disablement by Chemical Materials Agency, the 20th CBRNE Command, ECBC's Chemical Biological Applications & Risk Reduction (CBARR) capabilities and the US Army Medical Research Institute of Chemical Defense. The German Army also offered briefings on their capabilities that could be part of a multinational effort to eliminate chemical weapons.

Overarching Challenges Identified

"The only thing worse than fighting with your Allies is fighting without them."
-Winston Churchill

Information sharing was essential throughout the exercise and challenged by non-compatible platforms and classification policies. Both nations determined that an information sharing agreement established early would facilitate efficiency throughout all phases of the operation. Strategic messaging, for the multinational force as well as the local population, would be critical. Also identified was lack of CBRN-centric intelligence-trained personnel at each level of command, specifically the CJTF, and the need to create a CBRN Intelligence Fusion Cell/Center (Strategic to Tactical focus) for better CBRN analysis.

It was also determined that collaboration of intelligence would better focus efforts in locating, identifying, and containing WMD facilities and material. By leveraging both nations' Intelligence, Surveillance, and Reconnaissance (ISR) assets, continuous monitoring of WMD facilities critical in disrupting proliferation could be undertaken. It became obvious that all WMD Elimination / Disablement operations would be time and resource intensive. Site security operations would dominate maneuver commanders operations and may require additional training and equipment for the protection of non specialized CBRN forces.

For this TTX, the Allied Forces were invited by the newly established Host Nation Government (HNG) to provide security and stability while assisting in the disablement of their recently declared WMD programs left from the previous regime. It was determined early that full cooperation from the HNG and local nationals working within the WMD facilities would be essential in the WMD Disablement operation. This also expanded the mission of disablement to include not only WMD material, but facilities and equipment, as well as Subject Matter Experts working within the programs. Different methods were discussed on repurposing both facilities and staff in an effort to facilitate economic growth while insuring no future proliferation.

Chemical Weapons - Capabilities and Challenges

By applying lessons learned and experience from the recent Syrian Chemical Weapons Elimination, it was assumed that the Organization for the Prohibition of Chemical Weapons (OPCW) would be involved to provide oversight and transparency. It was learned that both Allies use different sampling procedures and it was agreed that both countries would consider using Allied Engineering Publication (AEP) 66. Additional legal oversight would be essential to ensure compliance with the Chemical Warfare Convention.

For this phase of the exercise it was estimated that it would take 60 days to setup eliminations equipment followed by 40 days of testing and systemization of a facility. Furthermore, an estimated 40-60 days of operation would be needed to complete the eliminating mission and an undefined time to conduct clean up and dismantling of the apparatus.

Biological Weapons - Capabilities and Challenges

During the Biological Weapon phase of the exercise it was clear that an additional staff of SMEs would be needed to advise in the execution. These included biochemists, biologists, and medical specialists. Biological detection and more specifically, identification, presented many challenges, primarily based on time and protection. Further challenging the staff was the fact that one of the biological facilities was collocated with an existing and operational hospital. There was detailed discussion on how to conduct disablement while isolating the medical facility and still providing medical service to the host nation. Quarantine and medical monitoring were also discussed and it became apparent that both nations have different standards, especially when discussing antibiotics and inoculations.

The biological phase presented an interesting challenge during the exercise, primarily due to the complexity in detection and identification. Though there was no biological release or event, understanding the existing host nation BW weapons program with facilities, stockpiles, and personnel became the focus. By applying lessons learned from the recent Ebola response both the US and Germany focused on containment, inoculations, protection, and quarantine. Information sharing became vital between both nations, but especially the Host Nation. Constant monitoring for any outbreak was essential. It was determined that this phase of the operation would be lengthy and require a dedicated task force with limited personnel working in the facilities and continuous medical monitoring. The use of collective protection was also discussed during this phase of the operation.

Decontamination methods and material differ between the two nations which led to a great deal of discussion in standards and a continued discussion of "how clean is clean"? Both nations could benefit even more in the future by actually getting hands-on experience with the equipment for detection, identification, decontamination, and protection.

Questions identified requiring to be addressed:

- Efficiency – verifying what is in a container without opening the container?
- What is effective Decontamination? (Bio-treatment and equip, Disinfected, Autoclave/Incineration)
- What expertise is needed? CBRN or Medical?
- How do we dispose of the waste product?
- Is there a difference between the weaponized and unweaponized biological [agents]?
- How does the CJTF to using civilian expertise?
- How does the CJTF integrate other organizations like the World Health Organization and Center for Disease Control?

Radiological Threat - Capabilities and Challenges

As with the Chemical and Biological programs, cooperation from the Host Nation was essential in the radiological elimination process. The existing facilities and staff where seen as key in locating storage and processing facilities as well as their history. It was determined that the radiological elimination would have been the most time consuming primarily due the required transportation and relocation of the material. As with the other phases, proliferation was of utmost concern and security of the facilities as well as border checkpoints would require radiological detection equipment.

It was also identified that information management and training would be important for both the security force and the local population. Leveraging the Host Nation leadership and its scientific community will help control any fears and present transparency to the operation.

Both nations possess airborne standoff radiological detection systems and their use played a key role in the detection and monitoring of radiological hazards within the Nuclear plant complex but throughout the country as well. Counter proliferation was a concern and both nations concluded that elimination went beyond just the material and facilities but to the scientists and staff. This network needed to be defined and understood. Support from the international community needed to be leveraged to assist in the transportation, disposal, or repurposing of materials and facilities. The scientists and staff would be employed to assist in the elimination.

Conclusion

As a result of the TTX, both the armies expanded their ATA to conduct another TTX or Training Exercise without Troops (TEWT) in the summer of 2016 hosted by Bundeswehr with the potential to expand into additional training events.

Overall the event was hailed as a success by both nations. All four multinational teams demonstrated cooperation and problem solving during the challenging exercise and lasting friendships were made. This exercise was the first and will guarantee future training and cooperation and better prepare both nations in the event of actual response.
The Way Ahead

Building on the success of the September TTX, the German and American Army staff talks of November 2015 solidified and underwrote even more future partnership. At an engagement at Fort Hood, TX between the 48th Chemical Brigade, 20th CBRNE Command and the Bundeswehr CBRN Defense Command in January 2016, an additional WMD-E exercise was planned for July 2016. This Training Exercise without Troops (TEWT) will be facilitated by the US Army Europe's Joint Multinational Simulation Center (JMSC) at Grafenwoehr, Germany and will build into a full scale Field Training Exercise in the spring of 2017. The continued cooperation between these two Allies in the realm of CBRN Defense is established as a model of partnership our Army.

Biographies

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20th CBRNE Command Transformation – Regionally Aligned CBRNE Task Forces

BG (Ret.) James B. Burton and COL F. John Burpo
U.S. Army, 20th CBRNE Command

As the U.S. transitions from combat operations in Afghanistan and publishes new strategic defense priorities, the overarching theme is balancing capabilities, capacity, and readiness, while operating with fewer resources. [1,2,] This drives a need for solutions to maintaining and increasing capacity to the greatest extent possible, with little to no growth, and in some cases, with a reduction in organizational structures. The global landscape has fundamentally changed with increasingly hostile, fragile, or failed states posing a continued threat of transnational, non-state organizations, and alliances seeking to expand their influence. The complexity and uncertainty of this rapidly changing strategic environment demands timely and mission-focused decisions about future capability and capacity needed within our Army to address the increasing momentum of human interaction, threats emanating from dense and weakly governed urban areas, the availability of lethal weapon systems, and the proliferation of CBRNE threats.[3] The risk of Weapons of Mass Destruction (WMD), the continued threat and expanded use of the IED, and the acquisition, proliferation, or use, and prevalence of asymmetrical CBRNE threats has intensified, creating a range of potential futures that suggest the employment of complex CBRNE hazards against US interests and allies is an increasing risk. The cost of insufficient preparation against these hazards is substantial.

This paper describes the 20th CBRNE Command transformation efforts in terms of the operational environment, the Command's functional organization and mission sets, the CBRNE task force construct, the regional alignment of forces concept, and the way forward. Ultimately it defines the CBRNE forces concept with regionally aligned focus, and the CBRNE planning and operational capabilities that will improve the Army's and the Nation's CBRNE Capabilities. In this paper, the term CBRNE includes all Chemical, Biological, Radiological, Nuclear, and Explosive threats. Expanding on the scope of the Joint WMD/CBRNE definition, and consistent with the Army's definition, the "E" represents the full range of Explosive threats, from low to high yield, and captures the subset of critical tasks that our EOD Soldiers perform from unexploded ordnance, to improvised explosive device (IED) defeat.[4,5]

Operational Environment

Adversaries will continue to look to the use of CBRNE capabilities as a way to maintain an asymmetric advantage over U.S. forces, and our allied and coalition partners. Adversaries will use CBRNE capabilities to shape the operating environment to inflict casualties, create conditions to deter or defeat entry operations, and erode public support and the basic will to fight. While difficulty in the acquisition, development, and delivery of threats increases from Chemical to Biological to Radiological to Nuclear, with low-yield explosives remaining cheap and easy, accelerating technological advancement and communication will enable greater ease in development and employment. This includes not only single threat types, but also more complex hybrid CBRNE threats delivered in parallel or serial within a given area of operations.[6] In the same manner in which the 9/11 terrorists were able to couple innovative delivery means with a combustible fuel, we must anticipate unique and coupled delivery of multiple elements of the CBRNE threat spectrum, as well as the continued use of improvised explosive devices as a persistent tactical threat. Within this context, the simultaneous presentation of hybrid CBRNE threats within an area of operations requires unity of command of special purpose, highly technical forces, commanded by trained leaders with the knowledge of how best to employ them and to appropriately synchronize an effective response. Inefficient, ad hoc solutions, or "pick up" games resulting from a last minute assembly of forces, is unacceptable.[7]

In operational environments, CBRNE threats and hazards are not limited to military sources. CBRNE threats also manifest from industrial, energy, medical, pharmaceutical and academic research sectors, and may include an explosive component for dispersal. These threats and hazards present an integrated and complex threat environment by themselves. When these threats are linked with increasingly available technology, materiel and coupled to motivations contrary to US interests, they result in a threat profile that demands an integrated, multi-functional, CBRNE force to appropriately identify, characterize, assess, disable/render safe, exploit, eliminate and ultimately destroy these hazards.[8,9]

The 2014 Quadrennial Defense Review (QDR) highlights the need to adjust contingency planning to more clearly reflect the changing strategic environment by "employing regionally-focused forces to provide tailored packages that achieve critical global and regional objectives."[10] The Army Strategic Planning Guidance (ASPG) – 2014 states that, "Agile, adaptive, and integrated conventional forces, special-operations forces (SOF), specialized explosive ordnance disposal (EOD) and CBRN forces, and missile defense provide a unique mix of scalable and tailorable capabilities across the total Army."[11] The 2013 Army Strategic Planning Guidance (ASPG) also states the "Army will implement a regionally aligned force concept that leverages scalable capabilities to provide mission tailored forces to combatant commanders."[12,13]

Training and Doctrine Command (TRADOC) recently published "Force 2025 and Beyond" which outlines the Army Warfighting Challenges. Army Warfighting Challenge #5 clearly identifies that the Army provides the preponderance of forces and capabilities to counter WMD threats and CBRNE hazards in the land domain.[14] Further, Warfighting Challenge #6 identifies the role of the 20th CBRNE Command in the defense of the Homeland, and Warfighting Challenge #20 describes the need to develop formations capable of rapid deployment to achieve mission success across the range of military operations. These, along with the remainder of the Army's 20 Warfighting Challenges provide a framework which informs the organization, resourcing, training and employment of the 20th CBRNE Command. The equities shared in each of the warfighting challenges must not be approached independently, but integrally to ensure that the 20th CBRNE Command can fulfill its vital role in delivering ready, reliable and globally responsive CBRNE capabilities to meet the challenges of an increasingly complex operational environment.

20th CBRNE Command Overview

The 20th Chemical, Biological, Radiological, Nuclear, Explosives (CBRNE) Command is a highly-technical, special purpose, expeditionary formation that represents 85% of the Army's active component CBRNE capability with the mission to deploy and execute CBRNE operations worldwide. The command consists of more than 5,000 Soldiers and 225 civilians assigned across two Explosive Ordnance Disposal Groups, one Chemical Brigade, and a Civilian CBRNE Analytical and Remediation Activity. The 20th CBRNE Command is the Army's only formation with the specialized CBRNE capabilities and expertise required to operate effectively across the full range of CBRNE threats and hazards.

To better reflect the complete current and anticipated set of missions, orders, and taskings of the Command, Forces Command (FORSCOM) approved the following mission in July 2014: The 20th CBRNE Command deploys to support unified land operations and performs mission command for Army and/or Joint CBRN and EOD Forces to achieve National CWMD, Homeland Defense, and Defense Support to Civil Authorities (DSCA) objectives, while providing globally responsive CBRN and EOD forces to combatant commands. The corresponding Mission Essential Task List is: Conduct Mission Command; Command and Control a Joint Force Headquarters; Execute Combating Weapons of Mass Destruction Operations in Joint Operational Area; Provide Explosive Ordnance Disposal (EOD) Protection Support; and Conduct Chemical, Biological, Radiological, and Nuclear (CBRN) Operations.

In the homeland, the Command routinely engages and operates with and in support of Joint, Special Operations, Interagency, and International CBRNE organizations and entities, and:

- Performs daily EOD emergency response and Very Important Person Protection Support Activity (VIPPSA) missions (2200 and 750 respectively annually).

- Maintains forces on Prepare To Deploy Orders (PTDO) for the U.S. Northern Command Defense CBRN Response Force (DCRF)

- Provides CBRNE forces to Defense Support to Civilian Law Enforcement Agencies (DSC-LEA) ranging from bomb disposal in civilian communities to packaging and movement of Recovered Chemical Warfare Materiel (RCWM)

- Provides the Ground Collection Task Force for the FBI-led National Technical Nuclear Forensics (NTNF) mission Executes other special missions with recall windows ranging from 4 hours to 2 weeks

Concurrently, the Command also has:

- Forces deployed in support of U.S. Africa (AFRICOM), Southern (SOUTHCOM), Pacific (PACOM), and European (EUCOM) Commands

- Forces deployed in support of U.S. Central (CENTCOM) and Special Operations (SOCOM) Commands, primarily in Afghanistan supporting CIED efforts with EOD forces

- The CBRNE Analytical and Remediation Activity (CARA) typically engaged with three on-going RCWM remediation missions at Formerly Used Defense Sites (FUDS) and stands ready to support RCWM Emergency Response, Technical Escorts, and Analytical Laboratory Operations at any given time both CONUS and OCONUS

- Forces deployed in support of theater level exercises and in support of Combatant Commands Theater Security Cooperation Strategies and building Partnership Capacity initiatives

Ultimately, the vision of the Command is to provide the Army with ready, reliable and globally responsive CBRNE forces capable of leading and executing CBRNE related operations, anytime, anywhere.

CBRNE Brigade Task Force Organization

The Command recognizes that to respond to the changing strategic landscape and to operate effectively across the CBRNE spectrum, the historically singular view of the Command as focused only on CWMD and CIED must be broadened to one that is available for employment across the full range of CBRNE threats and hazards and across the full range of military operations. Rather than viewing the operational environment through a narrow CWMD lens, analyzing problems through a wider CBRNE perspective better illuminates challenges, and opportunities, and leverages the full capability of the Command.

Currently, 20th CBRNE Command EOD and CBRN units are organized functionally under three O-6 Commands, and one Department of the Army Civilian CBRNE Analytical and Remediation Activity. This construct does not capitalize on overlapping CBRN and EOD mission areas or core capabilities. The purely functional construct reduces flexibility and responsiveness in meeting global requirements. The geographically distributed nature of the Command with a response area that covers all of the Continental United States, creates inefficiencies in the execution of mission command, impacts negatively on readiness, and leads to ad hoc solutions when considering how to best resource emergent contingencies that call for the employment of both EOD and CBRN forces. Whether for training, contingency operations, or as an enduring organization, a multi-functional CBRNE formation delivers more flexible and capable regionally focused CBRNE forces; mitigates the challenges of historical ad hoc solutions to similar and anticipated future mission sets, and overcomes the Command's current unity of command and unity of effort challenges resulting from our widely distributed basing construct and complex mission profiles.

Task organizing into three, multi-functional CBRNE Brigade-sized Task Forces ensures our forces are properly organized, focused, positioned and prepared to respond globally to ever-evolving CBRNE threats (Figure 1). The Task Organization requires no MTOE change, and upon implementation:

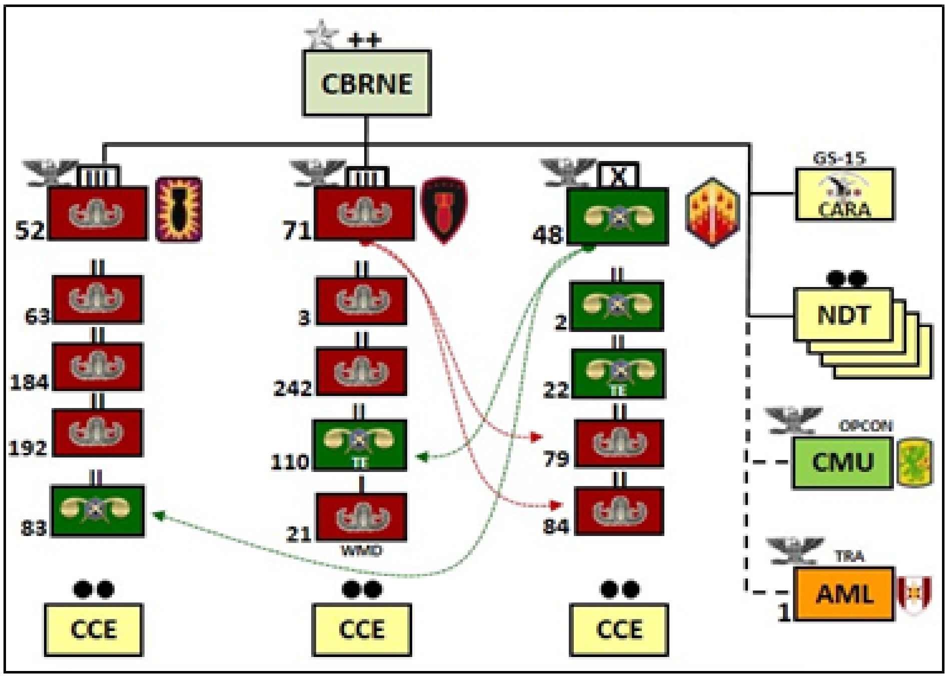

Figure 1. CBRNE Brigade Task Force Organization.

- Immediately improves and enables Unity of Command by reducing disparate command relationships, while increasing efficiencies in mission readiness and administrative functions across our dispersed formation
- Provides unity of effort and increases our ability to organize, train and project integrated CBRNE capability
- Enables the projection of mission command capabilities by echelon to better assure integration and proper employment of CBRNE forces, further enabled by technical reachback
- Does not impact on-going DSCA, DSC-LEA, or SOF support missions
- Positions the force to best support the Regional Alignment Force Concept and Army Contingency Force Package, consistent with Army and FORSCOM directives
- Maintains and ensures necessary technical oversight requirements
- Is completely reversible.

The 20th CBRNE Command must be appropriately integrated, at echelon, to provide deployable, expeditionary, and unified exploitation capability which enables decisive action across the range of military operations and the range of CBRNE threats and hazards.[15] This tactically and technically proficient Command must be sustainable with dedicated logistics solutions. The Command must be further enabled with expeditionary mobility solutions, and must be resourced with effective mission command capabilities, including robust technical reachback and mission command on the move capabilities to ensure our ability to meet our tailorable, scalable, globally responsive endstate. The formation must be proficient at Counter WMD operations to include WMD Elimination, Counter IED operations, Render Safe and Disposal of all CBRNE munitions or improvised devices, exploitation and analysis of CBRNE threats, decontamination of personnel, equipment and fixed sites, and capable of conducting large-scale CBRNE consequence management, Defense Support to Civil Authorities (DSCA), Defense Support to Civil Law Enforcement Agencies (DSC-LEA), and field analysis. Anticipated mission sets require both integrated multi-functional and purely functional forces.

Regional Alignment – Formations Organized for Execution

Each CBRNE Brigade Task Force (TF) is regionally aligned with the OCONUS Army Service Component Commands (ASCC) (Figure 2), and in support of the three CONUS-based Corps. TF 71 (CBRNE) is positioned in the Western U.S., and is aligned in support of I Corps with a focus on the PACOM AOR. TF 48 (CBRNE) is positioned in the central U.S. in support of III Corps and is focused on the CENTCOM, AFRICOM, and EUCOM areas of responsibility (AOR). TF 52 (CBRNE) is positioned in the Eastern U.S. and aligned with XVIII Airborne Corps in support of their Glob.

al Response Force mission, as well as NORTHCOM and SOUTHCOM.

In short, task organizing and regionally focusing the 20th CBRNE Command's subordinate formations improves readiness through unity of command, unity of effort, and increased "train as you intend to fight" familiarity between 20th CBRNE and supported forces. By focusing our efforts regionally and aligning in support of the Army Service Component Commands, through the three CONUS-based Corps, we are better prepared to fulfill both our homeland defense, and our expeditionary mission requirements without relying on traditional ad hoc solutions. Task Organization facilitates our leaders, Soldiers, and Civilians increased understanding about their potential primary operational environment. Task Organizing the Command enables our Soldiers to better train habitually with their partner CBRNE formations, and their supported maneuver formations, improving interoperability, while collaboratively examining specific regional threats, from current combat operations, to the range of threats found across the combatant commands.

Figure 2. CBRNE Brigade Task Force Regional Alignment.

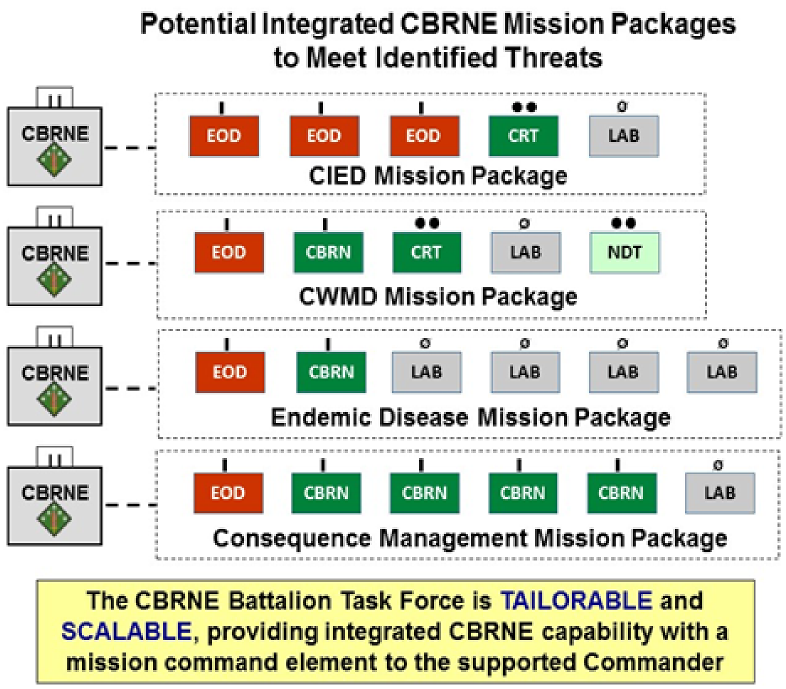

Figure 3. Potential Mission tailored CBRNE Battalion Task Forces.

Mission Tailored Task Forces

The CBRNE Brigade Task Forces depicted in Figure 1 represent a baseline organization to facilitate team familiarity through training and exercises, as well as a regional area focus. For contingency operations, task forces at the brigade and battalion level will be tailored to specific mission sets using the baseline task organization as a starting point. Figure 3 depicts tailored notional CBRNE battalion task forces across a range of representative mission sets. These task forces may be integrated, weighted for EOD, CBRN or lab capability, or functionally pure.

Echelonment of the CBRNE Force

Essential to the effective employment of the integrated CBRNE formation is unity of command and unity of effort. As such, it is imperative that a command and control element be identified and employed with CBRN and EOD forces, whether integrated or functionally organized, to ensure the appropriate integration and employment of these specialized forces with the supported unit (Figure 4). The employment of a CBRNE command and control element to synchronize the employment of CBRN and EOD forces, reflects a continued demand signal from supported Army and unified action partners.

Connection to the CBRNE Enterprise. Each CBRNE Brigade Task Force is enabled with an OPCON CBRNE Coordination Element (CCE), comprised of EOD, CBRN, Nuclear counter-proliferation, intelligence, and communications subject matter experts. Each CCE provides a planning, coordination, and synchronization extension of the 20th CBRNE Headquarters to regionally aligned CBRNE Brigades, as well as to the supported Corps Headquarters, and Army Service Component Command(s). Each CCE is enabled through robust technical reachback support to the 20th CBRNE Command HQ, and regionally focused on providing integrated CBRNE support across the specific Geographic Combatant Command Area of Responsibility (AOR).

The 20th CBRNE Command's unique technical reachback capabilities enable deployed CBRNE formations with a robust network, involving the subject matter experts from across the CBRNE communities of purpose, which empowers the lowest tactical elements with the expertise of the entire CBRNE enterprise through the collaborative power of information available to the joint, interagency, intergovernmental and multi-national partners. During operations, the 20th CBRNE Command's Operational Command Post (OCP) serves as the critical node between higher strategic level headquarters, the broader CBRNE enterprise/community of purpose, and the brigade and below CBRNE forces during tactical employment. Collaborative interaction between CBRNE echelons and reporting along the CBRNE chain in parallel to the supported units allows the 20th CBRNE OCP to maintain an authoritative, holistic, and integrated CBRNE Common Operational Picture.

Operational Employment. During contingency operations, CCE's are rapidly deployable and can readily integrate into a GCC, ASCC, and/or corps or division-level staff to assist with initial CBRNE planning and execution. A CBRNE Brigade Task Force Tactical Command Post (TAC) is available to rapidly follow to provide support to a corps/JTF echelon with the CBRNE Brigade TAC co-locating and integrating with the supported corps/JTF's headquarters. All CBRNE forces are enabled with technical reachback up and through the deployed CBRNE Command Posts, and ultimately back to the 20th CBRNE's Main Command Post (MCP).

If required, the 20th CBRNE Command's Tactical Command Post (TAC) can be deployed to provide the foundation of CBRNE planning and coordinating expertise provided by earlier deployed command posts, in order to provide tactical to operational level support as required. Ultimately, the Command's full Operational Command Post (OCP) can be deployed to integrate with a GCC or ASCC headquarters, and is available to exercise mission command over larger scaled CBRNE operations,

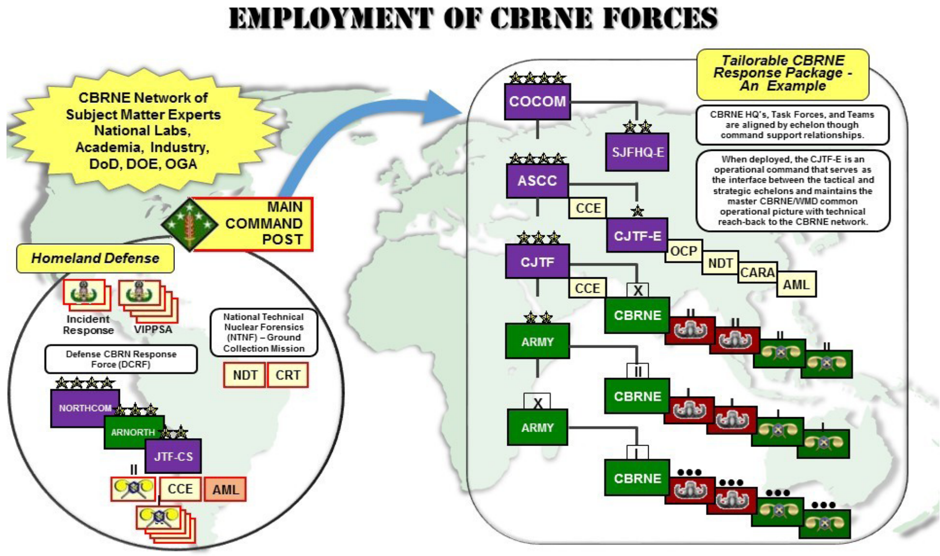

Figure 4. Echelonment of CBRNE forces.

as required. This tailorable and scalable echeloned concept of employment and integration allows for the rapid employment of CBRNE elements with their supported units and phased deployment into a theater of operations, while sustaining the enabling technical reachback to the CBRNE community of purpose.

Gaps and Challenges

However, integrated CBRNE formations are not available through a standard request for forces (RFF) construct. When analyzing standing OPLANs and Contingency plans, and when participating in Joint and interagency exercises, it is evident that a gap exists when considering how to best provide mission command of CBRN and EOD formations when deployed within a common operating environment. Recent experience in planning contingency and deliberate operations with the Global Response Force (GRF), CENTCOM, AFRICOM, and U.S. Forces Korea (USFK) emphasize the need for integrated CBRNE capabilities, subordinated to an integrating CBRNE mission command element. Changes to the current RFF and Joint Planning and Execution System (JOPES) are required to enable the requisition of tailored, multi-functional CBRNE formations.

Discussions and exercises with supported Army Divisions and Corps demonstrate both an acceptance, and an expectation that integrated, multi-functional CBRNE capabilities will be delivered to the supported command, complete with an integrating CBRNE mission command capability that can further augment the planning and coordination efforts of the supported force. Through Combat Training Center (CTC) rotations in Fiscal Years '14-15, we continue to shape our supported maneuver partners' understanding of our capabilities, while better informing this Command of how best to resource expeditionary and campaign activities.

These CTC rotations have enabled a thorough examination of required capabilities, and enduring capability gaps, particularly in the areas of communications, sustainment, mobility and protection. These rotations have also provided the environment to establish the doctrinal foundation for tactics, techniques, and procedures (TTPs) related to the execution of CBRNE operations.. Other enduring capability gaps include technical intelligence and fusion capability, organizational logistics, mission command, communications, and our subordinate forces' inability to provide readily available multi-functional, and modular CBRNE capabilities, based on our current organizational structure.

To close the doctrinal gap, we are working in close collaboration with the Maneuver Support Center of Excellence in the development of ATP 3-37.11, CBRNE Task Force Operations, with projected publication in March 2016. Additionally, we are partnering with the Joint Program Executive Office – Chemical and Biological Defense (JPEO-CBD), TRADOC, and the Defense Threat Reduction Agency (DTRA) for the development and implementation of an Advanced Technology Demonstration to address CBRNE technology gaps across all DOTMLPF domains and linked to the Army's Warfighting Challenge #5 (Countering WMD), which will inform capability gaps across all the Army Warfighting Functions where 20th CBRNE Command is a stake holder. These efforts help capture our operational concepts and lessons learned from supporting Unified Land Operations, Joint exercises, Mission Readiness Exercises, and CTC rotations.

Modernization Support

As the Command moves forward to modernize our CBRNE forces, we will identify change requirements beyond the reach and responsibilities of Forces Command. These requirements will be submitted as recommendations for force modernization, re-stationing, and synchronization of proponents of subordinate formations and functions for NDTs, EOD, CBRN, and analytical laboratories. FORSCOM's advocacy and leadership as we forward these recommendations to HQDA and TRADOC for incorporation into future programmatic functions such as the POM and TAA.

Conclusion

The 20th CBRNE Command is expected to provide the Army, and the Nation with Ready, Reliable and Globally Responsive CBRNE forces capable of leading and executing CBRNE related operations and activities, anytime and anywhere. To these ends, it is imperative that the 20th CBRNE Command transform its current functional organization into one which delivers three, multi-functional, regionally aligned CBRNE Brigade Task Forces as an important step in meeting the Army's Strategic Planning Guidance for this one-of-a-kind formation. Doing so provides our Army and our Nation an immediately improved solution for delivering integrated CBRNE capacity to meet expeditionary and campaign requirements.

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6. Aaronson, 111-124. Hybrid threats are defined in ADP 3-0 only with respect to forces and the hybrid CBRNE threat definition offered here includes the combination of forces and CBRNE elements they employ.
7. Deputy Secretary of Defense Paul Wolfowitz remarks to the National Defense University WMD Symposium, May 13, 2003.
8. Michael Aaronson, Sverre Diessen, Yves De Kermabon, Mary Beth Long, Michael Miklaucic "NATO Countering the Hybrid Threat," PRISM 2:4, National Defense University Press, 2012: 111-124.
9. Brian Fleming, The Hybrid Threat Concept: Contemporary War, Military Planning and the Advent of Unrestricted Operational Art, DTIC, 2011: 2.
10. 2014 Quadrennial Defense Review, dated 4 March 2014.
11. Army Strategic Planning Guidance–2014, p. 18.
12. Army Strategic Planning Guidance, dated 2013.
13 Presidential Policy Directive/ PPPD-17. June 14, 2012.
14. Force 2025 and Beyond: Unified Land Operations, Win in a Complex World. U.S. Army TRADOC, October 2014
15. The range of CBRNE threats and hazards includes, but is not limited to: chemical warfare agents, toxic industrial chemicals/materials, weaponized biological agents, biotoxins, endemic disease, radiological dispersal devices, medical/industrial radioactive sources, nuclear weapons, improvised nuclear devices, nuclear infrastructure, low to high yield explosives, conventional explosives, improvised explosive devices, and hybrid CBRNE threats and hazards.

Biographies

Brigadier General (Ret.) J.B. Burton is the former Commanding General of the 20th CBRNE Command. He has commanded at every echelon from Platoon to Brigade Combat Team. He commanded a mechanized combined-arms team during Operation Desert Shield and Desert Storm. He commanded the 2nd Battalion, 5th Cavalry in Kuwait during Operation Intrinsic Action. He commanded the 2nd Brigade Combat Team of the 1st Infantry Division in Baghdad, Iraq. Prior to his assumption of Command of the 20th CBRNE Command, he served as Deputy Commanding General for Maneuver of the 2nd Infantry Division. He received a MMAS in Military Science from the U.S. Army Command and General Staff College and a M.A. in National Security and Strategic Studies from the Naval War College.

Colonel F. John Burpo currently serves as the deputy department head for the Department of Chemistry and Life Science at the United States Military Academy, West Point. Previously he served as the Deputy Commander for Transformation in the 20th CBRNE Command at Aberdeen Proving Ground, Maryland. He received a Sc.D. in bioengineering from the Massachusetts Insititute of Technology, a M.S. in chemical engineering from Stanford University, and a B.S. in mechanical-aerospace engineering from West Point. As an artillery officer, he has served in airborne, armor, and Stryker units with humanitarian, peace keeping, and combat operational deployments to Rwanda, Bosnia, and Iraq.

Biological Decontamination: The Threat, Response Operations, and Challenges

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Release of biological hazards that place military forces in harm's way requires swift action to protect troops from contamination. Response to a biological attack would likely involve forces donning protective gear, operating equipment, and engaging systems to minimize exposure to and spread of agent. Consequently, combat effectiveness would be reduced and missions could be impacted in a bioagent-contaminated environment. This article focuses on the potential biological threat to military forces, response efforts to mitigate the threat to preserve combat operations, and various types of decontamination systems employed for microbial control.

Spectrum of Biological Threats and Decontamination Challenges

The biological threat is expansive, as it could involve any of a variety of pathogens (disease-producing microorganisms such as a bacteria, viruses, fungi, and protozoa) or toxins of biological origin (such as botulinum toxin produced by the bacterium *Clostridium botulinum* or ricin toxin produced by seeds of the castor bean plant). The diversity and complexity of potential biological attack sites and scenarios presents major challenges to establishing effective decontamination capability. A biological release covering wide areas such as a battlefield, transportation hub, sports arena, or agricultural field could require decontaminating vast spaces. Wide-area releases could also require decontamination of collaterally-contaminated items (structures, vehicles, equipment, and supplies), water systems, and food supplies. Decontamination of the interior of buildings, large structures, vehicles, or aircraft requires special treatment that does not degrade sensitive materials (electrical components, metals, and fabrics) and is able to permeate into crevices and confined spaces.

To be effective, decontamination strategies must address specific characteristics of a particular release scenario. Of primary importance, any strategy must include a decontamination formulation (typically referred to as a "decontaminant") that effectively kills a pathogen or neutralizes a toxin to reduce the health risk to an acceptable level. Application must provide intimate physical contact of the decontaminant with the biological agent that could be on surfaces, in air spaces, or in liquid or solid materials. A decontaminant can be liquid (such as chlorine bleach) that is applied in bulk or as a spray or mist to surfaces, foam that is applied to surfaces, or a gas or vapor (such as chlorine dioxide) that can treat air spaces and reach confined regions. The decontaminant must be effective under the physical and chemical conditions of the release site. Decontamination operations must also meet a variety of requirements and constraints that include ease of application, decontamination time, material compatibility, health and safety, environmental impact, storage stability, logistical demand, and cost.

Traditional decontamination strategies follow the assumption that systems able to effectively neutralize chemical agents can also effectively neutralize biological agents. In addition, *Bacillus anthracis*, the bacterium that causes the disease anthrax, is regarded as a great challenge among the biological threats since the organism can exist in the form of a spore and, thereby, tolerate decontamination treatments and persist in attack site environments that would be inhospitable for most other pathogens. Consequently, development of biological decontamination formulations has focused on the treatments that rapidly and effectively kill the anthrax spore.

A great variety of decontaminants are available. While they offer potential value to control biological threats, they are not without shortcomings for application to various types of biological attacks. Consequently, effective biological decontamination remains a formidable challenge. This article focuses on operations and systems employed for biological decontamination. An in depth review of decontaminant formulations would be an informative article for a future issue of the USANCA CWMD Journal.

Battlefield Contamination by Biological Agent Attack

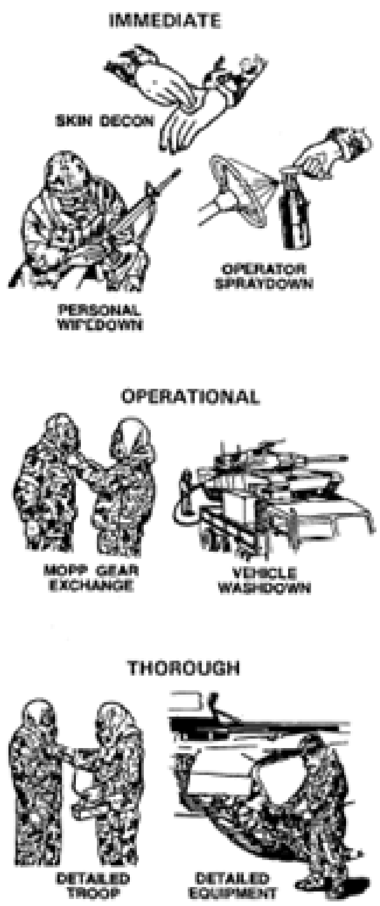
Biological attack of a battlefield would likely involve an airborne release of biological agent. The enemy *modus operandi* could be production of clouds of agent that swarm long distances to expose the health hazard to forces while contaminating terrain, equipment, vehicles, and supplies. Effective airborne exposure is possible with field delivery systems that produce aerosols as clouds harboring biological agent as small particles ranging in diameter from one to ten microns (one micron being about 1/200th the diameter of a human hair). As minute particles, biological agents could remain suspended within the released cloud and thereby travel with the cloud to reach and contaminate the intended attack site. If attached to larger particles, biological agent could quickly settle to the ground and not travel with the release cloud to the intended attack site. In addition, by being small particles, the biological agent, if inhaled by a human, could reach the lower depths of lungs where it would have a greater opportunity to cause disease or intoxication.

Fortunately, an effective aerosol attack of the wide area of a battlefield is a great challenge. Production and dissemination of aerosol clouds harboring biological agents as small particles requires expertise and sophisticated equipment such as aerosol-generating devices affixed to vehicles, aircraft, or drones. As simpler alternatives, conventional munitions (such as aerial bombs or missile warheads) could be modified to deliver biological material. However, munitions would likely not produce small particles needed for an effective biological aerosol cloud. As an additional challenge, atmospheric conditions (such as wind speed and direction) are unpredictable and can easily change the course of as well as disintegrate released attack clouds.

Regardless of the release conditions, biological attack of a battlefield would likely require decontamination operations and impact military operations. The extent of decontamination employed would be a function of the type and quantity of biological agent that reaches terrain regions, structures, vehicles, equipment, and most importantly, warfighters. Specific decontamination operations would address the commander's decision on regions and operations that are critical to continue military operations and complete the mission. For example, extensive decontamination could be implemented if forces must remain in contaminated regions as compared with the decision to decontaminate an egress to allow forces to vacate contaminate regions. Decontamination operations are presented in the next section.

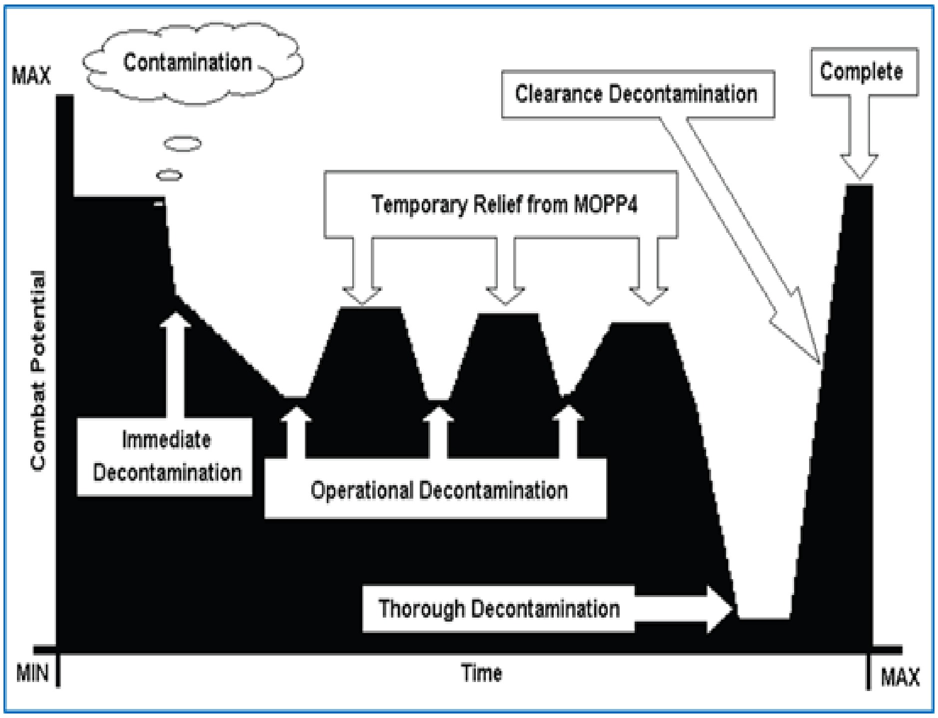
Combat Operations to Decontaminate an Attacked Battlefield

Once an attack release has been recognized, as by biological detection units, rapid response is required to minimize hazardous material transfer or spread from contaminated surfaces to clean surfaces. The military approach to decontamination is presented in the Multiservice Field Manual for Tactics, Techniques, and Procedures for CBRN Decontamination (FM 3-11.5). As a general approach for operational decontamination, the commander would apply available decontamination resources in order to sustain combat operations. This would be accomplished by decontaminating as soon as possible to reduce time required to be in higher MOPP (Mission Oriented Protective Posture) levels that restrict combat power. Also, equipment to be decontaminated would be prioritized on the basis of importance to the mission in order to conserve resources and sustain combat power. To limit spread of contamination, contaminated equipment and personnel would remain in the contaminated zone if needed decontamination materials can be transported to the attack site. Protocols developed to decontaminate chemical agents would likely be employed for biological agent decontamination since microorganisms are typically more sensitive to treatments than are chemical compounds.



A contaminated battlefield can undergo up to four successive decontamination levels, as immediate, operational, thorough, and clearance. The first three levels, as depicted by the figure to the left, would apply during a mission. Most likely an extensive process, clearance decontamination would follow a mission and yield a safe region that does not require use of protective gear. Upon knowledge of contamination, immediate decontamination is conducted by individuals to minimize casualties, save lives, and limit spread of contamination. Immediate decontamination methods include applying decontamination formulations to skin or removal of attack material by wiping or spraying. During this phase, a unit continues to "fight dirty" wearing MOPP gear in the contaminated environment. However, MOPP gear degrades performance and can lead to the decision to enact operational decontamination for temporary relief from MOPP. Operational decontamination allows sustainment of operations by reducing contact with and spread of the hazardous material as a means to limit duration of MOPP. Operational decontamination, conducted by individuals or units, is restricted to operationally essential equipment, materials, and areas. It can involve vehicle washdown and MOPP gear exchange. While operational decontamination allows continuation of the mission, thorough decontamination strengthens forces further by reducing contamination to a negligible level that reduces or eliminates the need for individual protective clothing. Thorough decontamination is conducted by units with support by chemical units to reduce contamination on personnel, equipment, materials, and working areas to the lowest possible level. Thorough decontamination can involve treatment of troops, specific detailed equipment, aircraft, and terrain.

Decontamination decisions for conducting operational or thorough decontamination are based on risk assessment with respect to mission, enemy, terrain and weather, time, troops available and civilian (METT-TC) considerations. This type of analysis enables a commander to decide if or when either of the decontamination processes is required for a given situation. Decisions, as depicted in the figure to the right, impact the level of combat potential with respect to effort for conducting decontamination and need for MOPP gear. Consideration factors could include, as an example, weather conditions such as rain that could wash biological contamination to collect at a region of lower elevation. Following a military mission, clearance decontamination can be employed as treatment of equipment and personnel to allow operations to be conducted without restriction. Because this treatment is more comprehensive, clearance decontamination may be limited to regions at or near an advanced base or other suitable facility. The process involves suspending normal activities, withdrawing personnel, and acquiring resources from an industrial base such as Army Materiel Command.



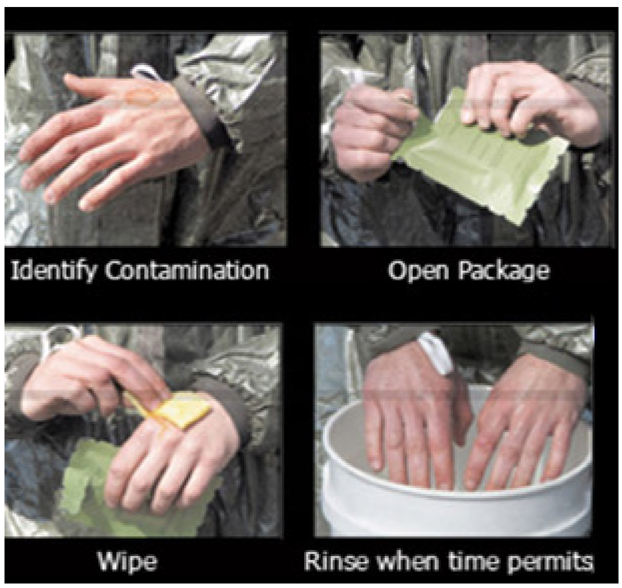
Combat potential achieved by succession of various decontamination processes.

Personnel and Skin Decontamination

Confirmed or suspected exposure of skin to a biological agent warrants immediate action for decontamination and takes precedence over treatment of other materials. For biological agent exposure on skin, a wash with soap and water would be employed to physically remove the material from the skin surface. However, because soap and water may not kill biological agents such as the anthrax spore, runoff water must be considered contaminated and should be contained and, if possible, treated to prevent spread of contamination.

If water is not available, personnel and skin decon systems developed for chemical decontamination provide alternate treatment for biological agent contamination. These kits are carried individually and have been approved by the FDA. Reactive Skin Decontamination Lotion (RSDL) as a current system is an improvement of the earlier M291 Skin Decontaminating Kit (SDK). As a water-based lotion, RSDL (less than one ounce) is contained in a foil pouch with a sponge applicator. The lotion contains compounds that desorb, retain, and sequester chemical warfare agents, including a toxin (T-2) produced by a fungus. Treatment of biological agents would primarily result from removal of material from the skin surface by wiping with RSDL. A video of the RSDL process can be viewed at https://www.youtube.com/watch?v=a8UuwY11WgE.

In response to many personnel becoming exposed to a biological agent, mass decontamination procedures are conducted as quickly as possible to minimize exposure while also practicing contamination avoidance. For personnel not wearing protective gear, uniforms are removed outside of the contaminated area and personnel shower for 0.5 to 3 minutes with high-volume low-pressure



Skin decontamination process using a foil pouch.

(50 to 60 psi) water. Gentle rubbing (with hands, cloth, or sponges) with care not to spread contamination to the mouth, nose, or eyes will improve agent removal. A second decontamination shower with soap would ensure adequate physical removal of biological material. Portable shelter systems with showers are commercially available. Since washes will not neutralize biological agents, shower water must be collected and, if possible, treated to prevent further contamination.

Surface Decontamination

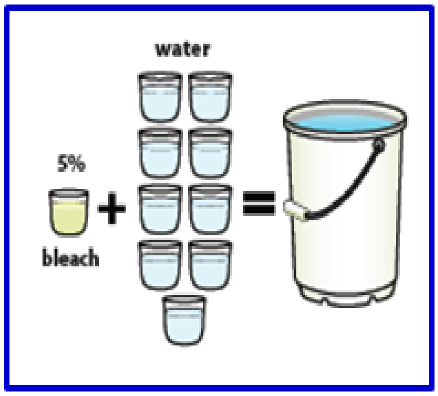
A biological attack scenario, such as relase of agent on a battlefield, would likely call for decontamination of inanimate surfaces such as pavement, building exteriors, vehicles, and equipment. Surface decontamination involves treatment to kill, neutralize, or remove biological agents that have deposited on surfaces of the immediate and surrounding areas of an attack. Surfaces could be treated by washing with high volumes of water or soapy water (unheated or heated) to remove biological material by ablution. However, washes and rinses could contain infectious pathogens or poisonous toxins and thus would require collection to control liquid runoff. In addition, water-based washes would not be suitable for sensitive equipment or materials. Consequently, use of decontaminants that inactivate biological material could be the preferred approach for microbial control. Ideally, a decontaminant must be strong enough to kill *Bacillus anthracis* spores on a surface. However, strong treatments could degrade sensitive materiel or impact the environment. Thus, it is crucial that selected treatments meet requirements for adequate decontamination while preserving the integrity of the materiel and environment.

While a variety of decontaminants are effective against bioagents under ideal conditions of a test laboratory, characteristics of material surfaces can impact decontamination efficiency. Smooth, non-porous surfaces that are impervious to liquid or small particles are easiest to treat since decontaminant can effectively contact biological agent residing on the surface. Non-porous materials include processed metals, glass, some plastics, and Chemical Agent Resistant Coating (CARC) paint. Surfaces of porous materials (such as concrete, asphalt, wood, fabric, and carpeting) present challenges since decontaminant might not reach biological material sequestered within the depths of the material matrix. Decontamination can be an even greater challenge with complex materials (such as terrain soil and vegetative) due to irregular surface architecture in addition to high porosity.

Traditionally, chlorine bleach (sodium hypochlorite) has been regarded as an effective decontaminating agent for both biological and chemical agents. A strong chlorine bleach solution of 0.5 percent is typically employed to clean and disinfect surfaces, objects, and body fluids. Using commercially available bleach which is typically about 5 percent, a working solution can be prepared by mixing 1 part bleach with 9 parts water as depicted in the diagram. Disinfectant effectiveness can be increased by mixing white vinegar with bleach to produce an acidic solution (lower pH). Stock bleach is alkaline (about pH 12) and as such is stable for many months. However, stock or diluted bleach is predominately hypochlorite (OCl-) which as a chlorine molecule is not the more potent form for killing microorganisms. The more potent chlorine molecule (hypochorous acid as HOCl) can be generated by lowering the pH of the chlorine solution with vinegar. To safely prepare acidified chlorine solution without generating chlorine gas, first mix 1 part stock chlorine with 2 parts water, then add 1 part white vinegar, and then add 6 parts water. Greater disinfectant strength of acidifed chlorine bleach was demonstrated in the laboratory with *Bacillus anthracis* spores deposited on various types of surfaces.

Chlorine-based disinfectant is also available as stronger formulations such as supertropical bleach (STB) and DS2 (Decontamination Solution 2). Compared with standard chlorine bleach, STB and DS2 are stronger biocides, more stable, and designed for decontamination operations. However, although very effective for killing

Container of DS2.



Diluting 5% bleach to prepare a working decon solution.

biological agents, STB and DS2 present safety, environmental, and logistical problems. DS2 and STB are highly corrosive and incompatible with metals, rubber sealants, some plastics, fabrics, and electronics. In addition, their use can generate hazardous waste that requires collection or containment to prevent adverse environmental impact. The two formulations have storage restrictions and are prohibited from aircraft. DS2 is no longer produced and final stocks passed their expiration in 2004.

Foam being applied to an open field.

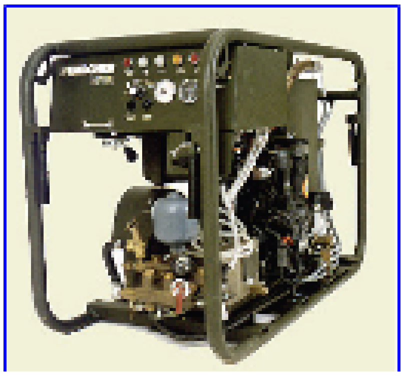
As a decontamination foam (DF) developed more recently by Sandia National Laboratory, DF200 is a mild, non-corrosive alternate to caustic decontamination formulations. DF200 effectiveness against various biological agents and pathogens, as well as chemical agents and compounds, has been demonstrated by civilian and military laboratories. DF200 has demonstrated effectiveness with a variety of complex surface substrates, including concrete, plastic, wood, and carpeting. Consisting of materials similar to those found in soap, DF200 exerted no health effects 24 hours after exposure on human subjects of a toxicology study. Currently marketed and commercially available as EasyDECON DF200, the formulation can be applied as a foam, liquid spray, or fog for suitability with a given contaminated material. The foam offers utility for decontamination treatment of wide areas, including vertical surfaces. However, since the foam could require removal by water rinses or vacuuming following treatment, the DF400 was also formulated as a liquid spray for sensitive surface materials or as a fog to permeate crevices and confined spaces of equipment, vehicles, or building structures. For personnel decontamination, DF200 is also marketed as Personal Incident Decontamination Spray.

For spray decontamination treatment of materiel items such as equipment and vehicle components (steering wheels, tires, etc.), a portable decontamination apparatus (such as M11 or M13) can be employed to deliver bleach. If bleach is not available, hot, soapy water can be sprayed for treatment. Following spray application, surfaces are brushed and then rinsed with water. If soapy water is used instead of a disinfectant like bleach, precautions are needed for rinses and water runoff since soapy water removes but does not effectively kill biological agents.

Military Equipment to Decontaminate Surfaces

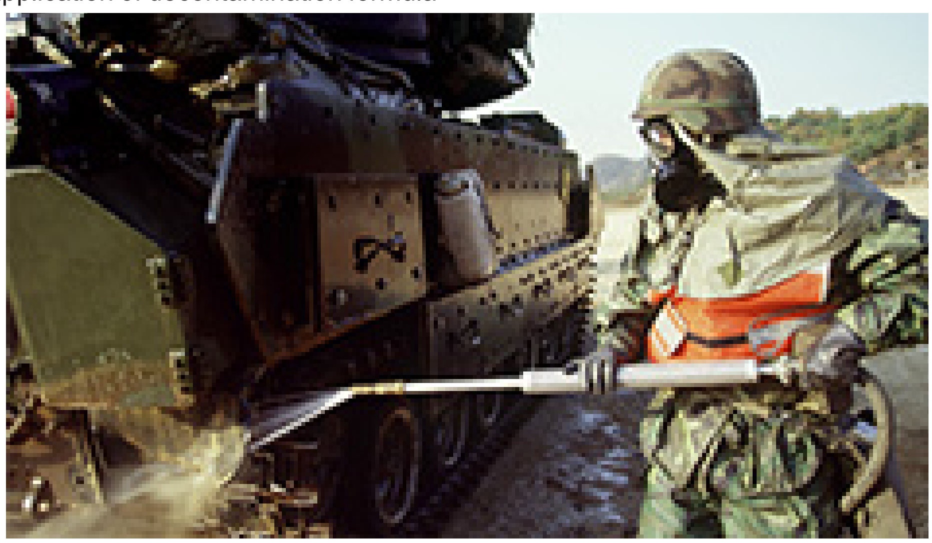
Military power-driven decontamination systems have been developed for application of decontamination formulations for specific types of items, materials, or areas that require treatment. While these systems were developed to decontaminate chemical agents, they could be employed for biological decontamination since microorganisms, including the anthrax spore, are generally more sensitive than chemicals to decontamination treatment.

These systems generate streams of pressurized water to physically remove contamination from surfaces. Decontamination of material items can be conducted using the Lightweight Decontamination System (LDS) M17A3 which is employed by the Army, Marine Corps, and Air Force. As a portable, engine-driven (gasoline or diesel) pump, the LDS delivers low-pressure, high-volume water (up to 9 gallons per minute) for immediate and operational decon op-



M17.

erations of equipment and personnel. The system can heat water up to 248°F for hot-liquid decon. The LDS can draw from a natural water source from up to a 30-feet distance and has a 3,000-gallon storage tank if natural water is not



M17A3.

available. The unit can be transported by a ¾-ton trailer, 5/4-ton cargo truck, cargo aircraft, or helicopter (sling load).

The Multipurpose Decontamination System (MPDS) M17 is an Army system designed for operational or thorough decontamination operations. The system can deliver (1) aqueous solutions or hot foam for material decontamination, (2) dry steam for equipment decontamination, and (3) warm shower water for personnel decontamination. The engine-powered high-pressure pump can receive various water sources, including seawater.

The M12A1 is an Army system employed for decontamination (operational, thorough, and terrain) and firefighting. The system delivers spray of water, STB slurry, or other decontamination formulations. The system consists of a 500-gallon storage tank, a pump unit, and a M2 water heater that are mounted on skids. The pump (centrifugal) is powered with a military standard gasoline or diesel engine. The heater is powered by a generator in the pump unit. The system can deliver 50 gallons of decontamination liquid per minute through each of two hoses. A personnel shower assembly is stored on the

FSDS in a civilian vehicle.

M12A1.

tank unit and assembled for a configuration to accommodate up to 24 personnel simultaneously. The unit is typically mounted on a 5-ton truck and can be dismounted to facilitate air transport.

The Fixed-Site Decontamination System (FSDS) is an Army system that employs compressed air to deliver foam. The system consists of a pump and tank for decontaminant formulation. The system may be applied for decontamination of (1) terrain using a spray bar mounted at the rear of a trailer and (2) fixed-site equipment and facilities using a deck gun mounted on a truck bed. In addition, a foam dispensing nozzle with a 100-foot hose can be employed for direct application of foam or to augment deck gun operations. While the FSDS is primarily designated for APODs and SPODs, the system could also provide capability for decontamination of main supply routes, vehicles, and aircraft.

Decontamination of Terrain and Wide Areas

Decontamination of vast areas of terrain would be a great challenge due to the immensity of material that would require treatment. Decontamination operations would likely be expensive, exhaust resources, and require considerable effort. In addition, the benefit may only be long term and not expedient to allow reduction in MOPP level. Consequently, a commander would likely not consider decontamination operations of a wide area as an option unless absolutely necessary. Decontamination, if executed, would likely be applied to limited regions to provide channels for movement of troops, vehicles, and equipment. As a more practical option, a commander may consider weathering. Natural environmental conditions of sunlight (ultraviolet radiation), temperature, and desiccation would be convenient and could provide a basic level of decontamination to expansive regions. Levels of many pathogens could be reduced considerably following hours or days of weathering. However, weathering can be slow or ineffective for hardy microorganisms such as the *Bacillus anthracis* spore.

As mentioned above, *Bacillus anthracis* presents a unique challenge to decontamination operations since as a spore the organism has innate tolerance to harsh treatments that effectively kill most other pathogens. In addition, the spore can thrive for years in soils of natural environments. Survival of the *Bacillus anthracis* spore is exemplified by the reported persistence of the pathogen on Gruinard Island, a remote uninhabited region off the coast of Scotland. In 1942 Porton Down scientists detonated bombs of *Bacillus anthracis* on the island and monitored the health of sheep as susceptible hosts to ascertain the feasibility of an “anthrax attack” by the Germans. As a testament to spore durability, the pathogen survived on the island for many years until extensive decontamination treatment was conducted in 1986. Treatment involved spraying 280 tons of formaldehyde diluted in seawater over about 485 acres of land. Warning signs were finally removed from the island in 1990, 48 years after the pathogen’s release.

Should a commander decide that wide-area decontamination operations are necessary, there are options. Considering biological material may only penetrate about a two-inch depth, terrain can be scraped with a bull dozer or road grader to remove contaminated earth or other soft layers. Alternately, contaminated areas can be covered with a 4-inch layer of earth, roofing paper, plastic sheets, or wood mats. Contamination can be flushed from surfaces with large volumes of water or hot soapy water and, if possible, collected in troughs or other areas of lower elevation. To kill microorganisms or neutralize toxins, STB can be applied. Dry mix STB can be spread on a solid surface or raked into soft surfaces of earth. STB slurry can be applied to terrain from a slow-moving vehicle using a spray hose attached to a M12A1. Operation with STB slurry requires specialized training and wearing Toxicological Agents Protective Aprons over MOPP gear.

In addition to the battlefield, biological attack of vast areas of the homeland could present a challenge to decontamination. Defense concerns for the potential wide-area attack release of anthrax spores were addressed by the Interagency Biological Restoration Demonstration (IBRD). The Demonstration conducted from 2007 to 2011 focused on a scenario involving anthrax spores released as aerosols in two 100-square-mile areas in Seattle, Washington. As an effort jointly led by DTRA and DHS, IBRD participation included DoD and Federal, state, and local government agencies to identify gaps and offer solutions to reduce time and resources for recovery and restoration following an urban attack. The effort included analysis of available decontamination systems that could be employed for the attack. The immensity of a wide-area attack is illustrated by projections of tens of thousands of people exposed, thousands of deaths, and more than ten years for recovery. The Demonstration culminated with a capstone meeting of various organizations.

Letters of the anthrax attack on the United States.

The need for next-generation technology to address the challenge of treating wide-areas contaminated with *Bacillus anthracis* spores was addressed by DTRA. The effort was initiated with a 2011 workshop of experts who were provided the opportunity to proposed novel strategies to effectively kill the bioagent with operations employing minimal amounts of decontaminant formulation applied to vast field areas. Proposed strategies included treatment to sensitize *Bacillus anthracis* spores to disinfectant for effective kill at low decontaminant doses. The concept of a treatment that disrupts the spore's protective casing and thereby sensitizes the organism to disinfection is presented in the Novel Strategies section of this article.

Decontamination of Enclosed Spaces

Biological contamination of enclosed spaces can result from a variety of possible attack scenarios. Compared with surfaces, enclosed spaces are complex and can pose a great challenge to achieving effective biological decontamination. A prime example of such a challenge is the 2001 anthrax letters attack of the U.S. homeland involving delivery of tainted mail to the Hart Senate Office Building, two postal facilities, and several news media offices. Anthrax spores as dry powder were released from envelopes and became airborne during postal processing and upon opening by office personnel. Following exposures that began on 18 September 2001 and lasting a few weeks, 22 individuals developed anthrax. Of those infected, five died from the disease.

System to fumigate enclosed space.

Decontamination of the buildings was a major effort. Building areas that tested positive for the bioagent spores were treated with various decontamination compounds that federal agencies and experts believed would be effective. Hard surfaces were treated with bleach, liquid chlorine dioxide, or DF200 Sandia foam. Large or highly contaminated areas were fumigated with chlorine dioxide, vaporized hydrogen peroxide, or paraformaldehyde. The fumigation processes allowed the decontaminating compounds to permeate airspaces and reach confined regions and inner depths of porous materials. Important sensitive items, such as electronics and computers, were treated offsite with non-destructive methods using gases such as chlorine dioxide or ethylene oxide. Gamma irradiation was also employed offsite for some sensitive items, but the treatment was limited due to cost and not being suitable for electronics. An analysis estimated the total cost associated with decontamination of the buildings to be about $320 million.

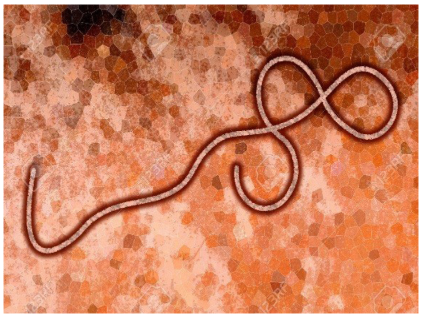
Decontamination of aircraft interiors is another great challenge due the size of the interior space and sensitivity of stationary components that cannot be removed for offsite decontamination

Hot, humid air treatment of C-130.

treatment. The sensitivity of electronics and other components of aircraft interiors precludes use of decontaminating fumigants such as chlorine dioxide employed to treat the buildings of the 2001 anthrax letters attack. As an alternate approach, the Joint Biological Agent Decontamination System (JBADS) program developed a hot, humidified air treatment to kill *Bacillus anthracis* spores under conditions suitable for aircraft interiors. Experiments conducted in laboratories demonstrated that hot, humid air could initiate germination of *Bacillus anthracis* spores (as well as spores of Bacillus thuringiensis) and thereby disrupt the spore's protective casing and lead to the organism's death. Practical application of this technology was tested through a Joint Capability Technology Demonstration (JCTD) that was successfully completed in January 2015. The JCTD involved release of Bacillus thuringiensis spores (commonly employed as a safe test surrogate of *Bacillus anthracis*) to contaminate the interior of a C-130 Hercules cargo plane at a test site at Orlando International Airport. Testers found the hot, humid air treatment (170°F, 90% relative humidity for 3 or 4 days), successfully killed spores to acceptable levels. In addition, subsequent tests also indicated the treatments did not adversely affect aircraft equipment or material.

Novel Strategies to Advance Decontamination Capability

As stated earlier in this article, the anthrax spore as a biological threat poses a major challenge to decontamination systems. As a dormant entity, the spore



Ebola viruses observed with electron microscopes.

Decontamination of a person to control spread of the Ebola virus during the 2014 epidemic.

could maintain its viability and infectiousness in a variety of austere environments for extended periods following its release as an attack agent. While application of disinfectants at elevated concentrations for long treatment periods could inactivate the spore, such a harsh treatment may not be acceptable for contaminated environments or materials. This is a significant issue for sensitive electronic and computer equipment.

As described above, the JBADS technology employing moderate heat with elevated humidity has been demonstrated to be a practical approach to inactivate bacterial spores in the sensitive environment of aircraft interiors. However, while JBADS offers potential value for decontamination of aircraft and perhaps other large materiel, the treatment must proceed a few days for sufficient spore kill. As an alternate approach for rapid spore inactivation, decontamination treatment could involve inducing the spore to germinate, the process by which the dormant spore awakens to become a metabolically active cell form. As a bacterial cell, the organism would be sensitive to antimicrobials and thus could succumb to low doses of a disinfectant following a few minutes of treatment. A variety of compounds are known to germinate the dormant spore. Combination of a germinating compound with disinfectant as an alternate strategy to decontaminate the *Bacillus anthracis* spore was presented by the author in the article "The Spore Casing as Defense for the 'Anthrax' Biological Agent" that was included in Issue 7 of the USANCA Combating WMD Journal.

Decontamination beyond the Battlefield: Military Support of the Homeland and Allied Nations

The U.S. military response to biological threats is not confined to the battlefield. The DoD plays a supportive role for U.S. homeland situations as a deliberate biological attack, accidental release of biological material, or significant naturally-occurring disease. In addition, U.S forces could be called to support allied nations challenged by a severe biological event, such as the West Africa Ebola Virus Disease (EVD) epidemic of 2014 which struck Liberia, Sierra Leone, Guinea, and Nigeria. Declared by the World Health Organization (WHO) as a public health emergency of international concern, the epidemic peaked during the summer of 2014 with hundreds of new cases reported weekly. After more than 22,000 cases (confirmed, probable, and suspected) and about 8,800 reported deaths, the EVD epidemic was declared ended by WHO in MAY 2015.

As directed by Operation United Assistance, the U.S. military as humanitarian support joined efforts of numerous U.S. agencies to combat the EVD epidemic. The U.S. military deployed about 3,000 U.S. troops to West Africa to provide logistical support, train more than 1,500 health care workers, and provide engineering assistance to build EVD treatment units and a hospital. U.S. military support did not include treatment of patients or operations that would place forces in direct contact with persons or materials known or suspected to harbor Ebola virus. Consequently, operations such as decontamination of personnel, as depicted in the left image, were not conducted by U.S. forces. In addition, rigorous precautions were established by the DoD to ensure force protection during support operations that could inadvertently lead to exposure to EVD patients or their bodily fluids. As guidance, the U.S. Army Public Health Command published technical information papers for decontamination of DoD-owned equipment used in areas of operation impacted by EVD and vehicles used for transportation of potential EVD patients. The documents state that the information is intended to supplement military decontamination procedures of FM 3-11.5 based on guidance from the CDC and WHO. Operation United Assistance was heralded as a U.S. military success. And with effective microbial control and decontamination precautions employed during operations, no U.S. troops became infected with the Ebola virus during the mission.

Biography

Jon J. Calomiris is a microbiologist at USANCA, Fort Belvoir, VA. He has a Ph. D. in microbiology from Johns Hopkins University. He previously directed microbiology and molecular biology research with the Air Force Research Laboratory at Aberdeen Proving Ground, Edgewood, Maryland. His email address is jon.j.calomiris.civ@mail.mil.

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Highlighted Courses available at the Defense Nuclear Weapons School (DNWS) and Defense Threat Reduction University (DTRU)

Theater Nuclear Operations Course (TNOC)

TNOC is the only course offered by a Department of Defense organization that provides training for planners, support staff, targeteers, and staff nuclear planners for joint operations and targeting. The course provides overview of nuclear weapon design, capabilities and effects to include U.S. nuclear policy, and joint nuclear doctrine. TNOC meets U.S. Army qualification requirements for the additional skill identifier 5H. The course number is DNWS-R013 (TNOC). Call DNWS at (505) 846-5666 or DSN 246-5666 for quotas and registration information.

Next class availability:
February 22-26, 2016 August 8-12, 2016

Nuclear Weapons Orientation Course (NWOC)

The Nuclear Weapons Orientation Course (NWOC) is a 4.5-day course that provides an overview of the history and development of nuclear weapons, management of the U.S. nuclear stockpile, and the issues and challenges facing the program. The modules focus on four functional areas: nuclear weapon fundamentals, nuclear weapon effects, nuclear weapons stockpile, and nuclear weapons issues. The course can be taught at the customer's location as a Mobile Training Team course (NWOC, NW110M).

Objectives
1. Define the scope of the national nuclear weapons program. Recall basic nuclear physics and materials
2. List key elements of nuclear surety
3. Recall development, testing, command and control, and weapons effects from stockpiled nuclear weapons
4. Name international agreements concerning nuclear weapons
5. Discuss current nuclear weapons issues

Next class availability:
February 8-12, 2016

May 17, 2016 - May 19, 2016 (MTT)
June 21, 2016 - June 23, 2016 (MTT)

Nuclear and Counterproliferation Officer Course (NCP52)

NCP52 is the Functional Area 52 qualifying course. Initial priority is given to officers TDY en route to a FA52 assignment or currently serving in a FA52 position. There is limited availability outside of the FA52 community. Please call the FA52 Proponent Manager at (703) 806-7866 to inquire on available seats.

Next class availability:
July 11, 2016 - August 5, 2016

U.S. Nuclear Policy

This course covers U.S. Nuclear Policy and its history; reviews NATO policy; discusses nuclear deterrence: theory, principles, and implications; discusses instruments of national power and implications for nuclear weapons; reviews nuclear surety and intelligence; discusses nuclear treaties and arms control.

This course is taught at the Defense Nuclear Weapons School (DNWS) Albuquerque, New Mexico.

Next class availability:
April 4-8, 2016

Email: dnws@abq.dtra.mil
Fax: (505) 846-9168 or DSN 246-9168
Online registration:
https://dnws.abq.dtra.mil/StudentArea/Login.asp

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